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# Journal

—OF THE—

# American Ceramic Society

*A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries.*

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# JOURNAL
OF THE
# AMERICAN CERAMIC SOCIETY

**A monthly journal devoted to the arts and sciences related to the silicate industries.**

**Vol. 2** **March, 1919** **No. 3**


## EDITORIALS.

### NATIONAL RESEARCH COUNCIL.

Pursuant to the request of the President of the National Academy of Sciences, that the American Ceramic Society nominate one representative for appointment as a member of the National Research Council in the Division of Chemistry and Chemical Technology, President Stull has recently nominated Mr. A. V. Bleininger to represent the Society in this Division and the formal appointment has been made by the President of the Academy.

In accordance with an executive order of the President of the United States, dated May 11, 1918, requesting the perpetuation of the National Research Council, a permanent organization for the Council has recently been adopted. In order to secure an effective federation of the chief research agencies of the country, it was decided that a majority of the members of each Division of the Council should consist of representatives of the leading national scientific and technical societies in the United States. On the recommendation of the Executive Committee of the former Chemistry Division, the new Division of Chemistry and Chemical Technology is to be initially constituted of representatives from the American Chemical Society, American Electrochemical Society, American Institute of Chemical Engineers, American Ceramic Society and Divisional nominations.

The initial meeting of the new Division was held in Washington on March 21st and 22nd. The salient features of the work accomplished at this meeting were the consideration of the establishment of research and industrial fellowships; a discussion of the formation of an International Chemical Society and the

promotion of international coöperation in publication; and a consideration of the patent situation.

At a meeting of the Executive Committee of the Division of Chemistry and Chemical Technology the following resolutions concerning the formation of a Committee on Ceramic Research were adopted:

"1. That the Division invite the American Ceramic Society to form with it a joint committee on ceramic research of which the representative of the Ceramic Society on the Division shall be ex-officio chairman.

"2. That the Committee consist of five members, two to be nominated by the executive committee of the Division and two by the Board of Trustees of the American Ceramic Society.

"3. That this committee undertake the following work:

"(*a*) Outline a number of important research projects of a character which can be undertaken in university laboratories.

"(*b*) Ascertain in the case of each project what institution is able and willing to undertake the investigation.

"(*c*) Raise by subscription from the industries a Fellowship Fund for each project, this fund to be used for the establishment of a two-year Fellowship, a portion of the fund to be available for traveling expenses, apparatus, supplies, etc. It shall be understood that all funds raised for such purpose shall be paid to the treasurer of the National Research Council, to be disbursed by him under the direction of the Committee on Ceramic Research; and that in connection with all such Fellowships regular reports shall be rendered to the chairman of the Committee and that a copy of the report be transmitted to each subscriber to the fund.

"(*d*) Make a study of the desirability and possibility of compiling a research census of the ceramic research in progress in the country, and, if the preparation of such an index is deemed desirable and practicable, undertake its compilation.

"(*e*) In coöperation with the Section on Industrial Research of the National Research Council, endeavor to secure the establishment of coöperative research laboratories in those branches of ceramics where such an undertaking seems feasible.

"(*f*) Secure if possible a statement of the plans of the Director of the Census with reference to collecting ceramic statistics in the coming census, and endeavor to secure such notification of, and additions to, these plans as it thinks desirable in order that such statistics shall be as complete and as useful as possible.

"(*g*) Take the initiative in attempting to secure the inauguration of cooperative effort by the appropriate agencies in the country in carrying out certain broad projects in ceramic research, such, for example, as the Cooperative Survey of Ceramic Raw Materials, initiated at the Pittsburgh Conference last May."

Upon the recommendation of President Stull, Mr. Homer F. Staley and Dr. Robert B. Sosman have been appointed by the Board of Trustees as the representatives of the American Ceramic Society on the Committee on Ceramic Research. The Society is to be congratulated in being so ably represented in the work of the Division by Messrs. Bleininger, Staley and Sosman. It is to be hoped that each member of the Society will lend his assistance to these men in the coördination and advancement of ceramic research in accordance with the comprehensive plan outlined.

## NATIONAL FIRE PROTECTION.

The considerations which made it appear desirable for the American Ceramic Society to become a member of the National Fire Protection Association were purely those of service, first to the country at large, by supporting and assisting in the important work of keeping down our enormous fire losses, and second, to that portion of the clay-working industry which produces building materials of various sorts.

The latter service should be two-fold, direct and indirect. The National Fire Protection Association establishes standards for many things pertaining to fire prevention and protection, including fire resistive construction. It would appear that the American Ceramic Society should be able to render a direct service to the industry producing structural clay products, by taking part in the drafting of structural standards. As to the indirect service, the support and assistance which the Society could give to the Fire Protection Association would be of benefit to the clay industry in common with all industries which produce fire resistive building materials.

It would appear that more active coöperation with the N. F. P. A. would strengthen the Society with certain branches of the clay industry which are now not as well represented in the Society as is desirable and that in the end this activity would be of benefit in a number of ways.

# ADDRESS OF THE RETIRING PRESIDENT.[1]

HOMER F. STALEY, Washington, D. C.

This is a significant moment in the life of the American Ceramic Society. It marks the opening of the twentieth anniversary meeting. Twenty years is a long time in the life of a society. In that time this Society has grown from a membership of a few score to an enrollment of over twelve hundred. Its publications have increased in amount until now each monthly issue of the Journal contains more material than appeared in the first annual volume of the Transactions. From a little known and less understood organization, the very name of which had to be explained even to clay products manufacturers, it has come to be the greatest technical organization in the world devoted to the advancement of the silicate and allied industries; an organization that is a power in these industries and capable even of giving material assistance to our country in winning a great war.

Custom has established that it is the special privilege, if not duty, of the president of a technical organization to give, on retirement from office, a review of the activities of the society which has honored him and to make such recommendations in regard to its future activities as seem to be desirable. It seems especially fitting that, at the close of twenty years of activity of our organization, such an address should be given.

It would be very easy and pleasant to spend an hour reviewing the many achievements of the Society during the past twenty years. It would be possible to dwell with profit on the activities of the Society during the closing year, which has been the most notable in many ways of any in the history of the organization. The Society has accomplished many things of which it can justly be proud. At present it is apparently in a very prosperous condition, both from the standpoints of membership and finances.

[1] Twentieth Annual Meeting, American Ceramic Society, Pittsburgh, Pa., February 3, 1919.

However, it should be realized by everyone that much of the phenomenal growth of the Society in membership and financial support during the past two years has been based on our promises to make the work of the Society of great practical value to its members. Many things have been done during the past year in fulfillment of these promises and to a large extent the Society is meeting the expectations of its members and friends. Other things remain to be done before the Society gives the full measure of service toward which we are confidently working. It is of these that I wish to speak.

A society like an individual grows both in form and in spirit. Because I believe that the development of form is secondary to development of spirit, and in truth, that the growth of the proper spirit will inevitably result in a workable form of organization, I will state a few recommendations for changes in the form of our Society and then emphasize the vital necessity for proper spirit in the conduct of the Society's affairs.

The changes in Society organizations and extension of activities I desire to suggest are:

(1) The enlargement of the scope of the Journal.

(2) The employment of a full-time secretary-editor.

(3) The establishment of permanent headquarters for the Society.

(4) Increase in the number of voting members.

(5) Definite decision as to the status of the cement and mortar industries in the Society's activities.

That the Journal should be enlarged in scope is well understood by everyone who has given any thought to the matter. The publication of the Journal is a decided improvement over the former practice of issuing only an annual volume of Transactions each year. It enables us to publish quickly the papers read at the annual and other meetings; attracts to our publication some papers that we would not receive under the old plan, and aids in keeping the membership in general in touch with the activities of the Officers, Board of Trustees, and various committees of the Society. The Committee on Publications and the Editor deserve great credit for the remarkably successful manner in which they have handled the launching of the Journal. The

starting of a new technical publication would have been a difficult problem at any time and was especially difficult at a time when the country was in the midst of a great war.

The Journal is not yet giving all the service of which it is capable and which is planned by the Committee on Publications. In order to hold and increase our membership, which means holding and increasing our advertisers, it is essential that each number of the Journal shall contain original papers or other material of practical value to each of the industries represented by our membership. It is hoped that the full development of the system of establishing Local Sections and Professional Divisions will result in the contribution of more papers, especially of the class designated as practical since they deal directly with factory problems. However, the Board of Trustees and Committee on Publications have been considering the advisability of establishing also a review department in the Journal with at least as many subdivisions as there are Professional Divisions in the Society. The plan proposed is not to attempt to duplicate the work of the existing abstract journals carrying ceramic departments by giving meager reports of everything published related to the ceramic industries, but to give rather full reviews of articles of real merit. To conduct such a department properly will cost some money, but the money spent in this way will undoubtedly be a good investment resulting in a larger list of members.

Another improvement in the Journal which has gradually been taking shape is the establishment of a fixed editorial policy. There are certain ideals toward which the Society is striving at all times, certain objects toward which it works at particular times. In the first class may be mentioned promotion of research and technologic development, the establishment of a high standard of professional ethics, and altruistic service to the ceramic industries in various ways. Among the aims of special efforts may be classed such movements as those for increase of membership, for contribution of papers to the Journal, or a large attendance at a meeting. The experience of the past two years has shown that in a society as large as this has grown to be, the new members can not be made enthusiastic for these ideals, and the membership as a whole can not be moved to action

in these special movements by an occasional letter from an officer or the chairman of a committee. It is coming to be the function of the editorial department of the Journal to place these questions before the membership in a systematic manner.

The employment of a full-time secretary-editor has been contemplated by the Society for several years. The lack of sufficient funds has been the deterring influence. We are glad to state that this obstacle has been overcome and funds for this purpose will be available from now on. The employment of a high-grade man to oversee the business affairs of the Society and to act as managing editor of the Journal is necessary to the future success of the Journal and of the other activities of the Society. Many of the Society's activities can be conducted largely through the agencies of the Board of Trustees, Sections, Divisions and Committees; but in addition to these we should have one man whose sole business in life shall be to attend to the affairs of the American Ceramic Society. The Secretary will be kept very busy indeed maintaining a voluminous correspondence, in overseeing the business affairs of the Society, in editing the Journal as to substance and general form, in writing editorials and in securing advertisements. The Society has few men who can fill the position properly and probably most of these will not care to consider a position so insecure of tenure and exposing the occupant to so much criticism. The best man available should be secured; and then the members of the Society should remember that while he will be the servant of the majority of the membership, he will in no sense be subject to the criticisms or wishes of the individual members. In order that the position may be removed from the field of petty politics and that the occupant may be given some assurance of continuity of employment as long as his work is considerd efficient by those in a position to know, it is desirable that the full-time secretary shall be hired by the Board of Trustees, rather than elected by popular vote. This is customary in other societies and can be arranged for by a simple change in the Rules.

The establishment of permanent headquarters for the Society is another corollary of the hiring of a full-time secretary. During the past year the Society seems to have been scattered all over

the country. Some of the Society's mail has gone to the printer, some to the Editor, some to the Secretary and some to the President. Other technical societies have found it advantageous to establish permanent headquarters in some large city, and no doubt the prestige of our organization and the effectiveness of its work will be increased when we are able to do the same.

The proportion of voting members in the Society's list of members should be materially increased. A start has been made in this direction by the alteration of the Rules so that presentation of papers is no longer the sole basis of elevation to membership. Nominations for elevation to active membership in accord with the new regulations have not been as numerous as the Board of Trustees has wished. It is hoped that a large number of nominations will be made during the course of this meeting.

It has been suggested that the grade of Associate Membership be abolished and that all members now in that grade be made Active Members. From the standpoints of democracy and equality of voice in Society affairs, this change would be admirable. However, several grave objections to this procedure should be taken into consideration. It may seriously interfere with the acquisition of members if we raise either the initiation fee or annual dues of new members. There is no need to dwell on this. On the other hand, we should not reduce the income from active memberships. From the standpoints of service to the greatest possible number of people in the ceramic industries and of increasing our possible revenue from advertising in the Journal, it is a good policy for us to carry a certain percentage of members at a loss as far as direct income is concerned. We are now doing this with all associate members of more than two years' standing. For several years the expenditures of the Society have averaged close to eight dollars per member. During the past year it was ten dollars per member. In the interest of good business policy and of fairness to our contributing members, the type of membership that does not pay its way should be reduced to a minimum rather than voluntarily increased.

In the interest of continuity of Society policy it is advisable that members serve a probationary period before being given the voting power. This is a certain kind of Society with certain

ideals. Whether or not it is the best possible type of organization or its ideals are the most laudable, the fact remains that the Society has grown and prospered under this system, and we are reasonably certain that it will continue to prosper if these policies are continued. We know how our present Active members will vote on any proposition involving departure from the fixed ideals of the American Ceramic Society. We know that after a man has been an Associate member of the Society for a few years and has assimilated the spirit of the Society, he too will strive for these same ideals.

The present Rules are really quite elastic on the subject of elevation of Associate members to Active membership. The only requirements are that "Active members must be persons competent to fill responsible positions in the silicate industries," and that they shall be nominated in a certain way and approved by the Board of Trustees. Under these rules if it is the wish of the Society the Board can approve the elevation of any member holding a responsible position in ceramic work as soon as it is satisfied that he is interested in the work of the Society and is sufficiently conversant with the spirit and aims of the organization to be intrusted with the voting power. It should be realized that it is rather difficult for any body of men to decide in a manner satisfactory to everybody concerned who are and who are not worthy of elevation to active membership. Another weak point in the operation of the present Rules is that nominations are required and the present active members will not take the trouble to make nominations. The Board of Trustees should be empowered to act in this matter on their own initiative if they so desire. This is usual in other large technical societies.

The above methods of operating the Rules for elevation to Active membership will augment the income of the Society very materially by placing the bulk of our memberships on a self-supporting basis; will enable the Society to honor new associate members rendering special service to the Society or the silicate industries; and will confer the voting power on all qualified to exercise the privilege. It has the additional advantage that new members can enter the Society at a comparatively low rate; and, since acceptance of Active membership is not compulsory,

they can continue at this rate if they are not interested in becoming Active Members.

If the Society wishes to have Associate members elevated to Active membership on the basis stated above, and there is serious question of our ability to do this under the present Rules, these should be amended. If this is done I would suggest that at the same time the initiation fee for Associate Membership be abolished. Otherwise we will be charging a member two initiation fees in a short time. The abolition of the first fee will greatly facilitate the process of getting new men interested in the work of the Society and thus increase our income from advertising and ultimately from active memberships.

As stated above the alternative plan of making all individual members active members has much to recommend it. May I suggest that if this plan is adopted the initiation fee be abolished and the annual dues be raised to ten dollars? The total income from each member would be about the same under the two plans.

The American Ceramic Society has always claimed that the cement and mortar industries were allied to the distinctively ceramic ones. These industries have refused to recognize this claim, largely because in our literature we have attempted to base the claim on similarity of raw materials. The true kinship is one of technique and technology in that the clay products, glass, enamel, artificial abrasive, cement and mortar industries all make products from non-metallic raw materials in a large way by the use of fire. They use the same general type of equipment and have to deal with the same pyro-chemical and pyro-physical processes. They are allied industries in the same degree that the various metallurgical industries are allied.

The lime manufacturers have recently admitted this common interest and the National Lime Manufacturers Association has designated the Journal of the American Ceramic Society as the official organ for the publication of the technical papers of that Association. We are in a position, therefore, to obtain some memberships and subscriptions from the 1300 members of the National Lime Association. This will result in the formation of a Lime Division in our Society and the publication of considerable material on the technology of lime in the Journal.

To the best of my knowledge the claim of similarity of technique has never been officially presented to the associations of cement and gypsum manufacturers. They both persist in believing that their industries are more closely allied to the purely chemical industries than to the ceramic group. Therefore, although we have received a number of contributions dealing with the technology of cement and gypsum products' manufacture, for which we thank the authors, we have never received any appreciable recognition or financial support from these industries. It is not fair to the industries that are supporting the Society for us to continue to publish material in the interest of industries that give us no support. A decision should be made. If it is possible to gain the support of cement and gypsum industries, an energetic effort to do so should be made. If it is not, we should cease to publish material relating to these industries and spend our money and energy in more receptive fields.

In the past, there has been some antagonism between cement manufacturers and manufacturers of crude clay products, on account of these products being sold for the same uses. This antagonism is dying out as the relative merits and suitability for specific uses of the various products is becoming better known. In the near future we may hope to see cement products and burned clay products sold as complementary materials rather than as antagonistic ones. However, the American Ceramic Society is interested in the making only of cement and burned clay products and not in trade rivalries. No trace of this rivalry should be allowed to appear in our publications or discussions.

The Society has some of the external form of a large society, and is rapidly developing the spirit of one. The form of an organization is merely an incidental shell: the spirit animating the organization is the essential substance that determines whether or no it shall be truly great and effective in its work. From the very beginning, the American Ceramic Society has been animated by high ideals and in many ways by an admirable spirit. The spirit of mutual helpfulness of member to member in solving technical problems has made membership in the Society a joy and an inspiration. The altruistic service to the ceramic industries so ably rendered in many ways in the

Society's activities is a fine example of the successful following of a high ideal. I would not change in the least the spirit of the Society in these respects. They are elements of greatness that make us all proud to be members of the American Ceramic Society.

A spirit of great courtesy and consideration for the feelings and wishes of the individual members of the Society has marked the conduct of the Society's business. This is a beautiful spirit and was very admirable in the early days of the Society, but it is not one in which a great and complex organization, such as the American Ceramic Society is coming to be, can be operated. The inevitable result of this spirit has been that a few members have come to feel that the Rules should not be adhered to strictly, that they should be ignored in some cases and special interpretations put upon them in others.

The Society is now so large and its organization is so complex that the only way its business can be conducted efficiently and without friction is by strict adherence to the Rules. These are the statements we have published of the methods in which the Society's business shall be conducted. As long as it is conducted according to these statements, no one has the right to claim lack of consideration. To permit one member to break the Rules is not an example of courtesy to him, but of injustice to a thousand other members.

In place of the spirit of consideration for individual members, there is developing a desire for orderly conduct of the Society's business and a spirit that puts the vote of the majority above individual wishes. This is the spirit of true democracy, the spirit that made Rome the ruler of the world, and the spirit that animates every great and successful technical organization in existence today. It is the privilege of the Society to alter the Rules; but as long as a rule stands on our books, every member should conform to it whether he personally thinks it is wise and just or not. The will of the Society must take precedence of the wish of the individual.

In one other respect the spirit of the Society should be changed. This is essentially a coöperative organization for the reading and publication of original papers. The fact is that the great majority of our members do not coöperate; they do not present

papers. Only about ten per cent of our membership contribute papers in any one year. About half of these are regular contributors. Five per cent of the membership of the Society has done seventy per cent of the work that has made the Society possible. This is deplorable. Every member of the Society should feel it his duty to present a paper or a short note on some subject at least every other year. Every man in the ceramic industry has opportunity to collect sufficient data to do this. There are very few who lack the ability to present such data in plain-straight-forward English. The real explanation for the dearth of papers is the refusal of the majority of our members to make the effort necessary to write up the data in their possession. They seem oblivious to the fact that the men who do prepare papers are spending time and labor for their benefit. Of course, all members pay dues, but these do not pay for papers—in the case of Associate members they do not even pay for the paper and printing of the Journal.

If this Society is to live and grow and expand, it must have an abundant supply of original papers on ceramic subjects. No plan of reorganization, no activities of committees, no growth in membership, will compensate for the lack of these. All the other activities of the Society are subordinate to and complementary to the one vital function of the publication of ceramic literature. It is probably hopeless to expect that the ideal of every member a contributor will ever be attained, but this is the point toward which we should strive. Every member should realize that he is not doing his full duty to the Society and to the ceramic industries if he does not make the contributions of which he is capable, even at the expense of considerable effort.

In closing, gentlemen, I wish to assure you that I believe the Society is progressing rapidly, that it is making real progress toward becoming a great Society both in form and spirit, and that I firmly believe that in the next few years we will see a remarkable expansion in the membership, activities, and influence of the American Ceramic Society. Permit me to thank you also for the honor you have conferred on me, and to thank you all, especially the other officers, members of the Board of Trustees, and committees for your efficient coöperation in the work of

the Society during the year. To be president of a large technical organization, such as this has come to be, is an interesting psychological experience. To me it has meant an insight into human nature that could probably not have been gained in any other way. It has meant lots of work, lots of trouble, but also lots of fun.

# ORIGINAL PAPERS AND DISCUSSIONS.

## THE EFFECT OF TIME AND TEMPERATURE ON THE MICROSTRUCTURE OF PORCELAIN.[1]

By Albert B. Peck, Pittsburgh, Pa.

### Introduction.

Many investigators have studied the microstructure of porcelain with regard to the development of the several constituents, particularly the sillimanite at different temperatures, but in all the literature on the subject there appears to be no record of any well-defined effort to correlate the time effect on the sillimanite and quartz with that of temperature. This assumes some importance in view of a recent contention that the constitution and microstructure of porcelain bodies is dependent chiefly upon the temperature of burning and in only a relatively small degree upon the differences in length of burn as will be found in the practices of individual concerns.[2] The use of this principle as a guide in the prediction of the burning temperature of commercial bodies by a microscopic examination has brought forth criticism from Mellor[3] who argues that the evidence as advanced by him tends to show that extended time can do the work which requires a higher temperature with a shorter time and that sillimanite crystals develop much more freely in certain mixtures than in others composed of the same constituents but differently proportioned. The development of sillimanite, therefore, can not be used as an indicator of the burning temperature.

The statement that the time element is relatively small in

[1] By permission of the Director, Bureau of Standards.

[2] Bur. Standards, *Tech. Paper* **80**, 33; *Trans. Am. Ceram. Soc.*, **18**, 377–423 (1916).

[3] *Trans. Eng. Ceram. Soc.*, **16**, 71 (1916–17).

importance as compared to that of temperature strikes one immediately as surprising since it is in direct opposition to well-established facts. The Geophysical Laboratory has shown that impalpable amorphous powder of CaO, obtained by the calcination of $CaCO_3$, when heated for a week at a temperature of 1300–1400° C (1000° below its melting point), results in a product which is crystalline and resembles, in all respects, CaO which forms out of melts of different compositions. This principle is much used by them in their work to obtain in crystalline form compounds which are unstable at their melting point or to increase the size of crystals for microscopic examination. If this is true in such silicate work, it seems reasonable to suppose that increased length of burning should produce marked effects on the microstructure of porcelain.

Moreover, porcelain represents a system which is in incomplete equilibrium. The nearest approach to equilibrium in porcelain is in high-fired bodies consisting of glass and sillimanite. There may be a question whether this represents true equilibrium but there can be no doubt that ordinary porcelain bodies represent incomplete equilibria because the reactions between the constituents can be observed as they take place, stopped or prolonged simply by varying the elements of time and temperature. It appears, therefore, that the longer the action takes place, the nearer should it approach an equilibrium and the greater should be its difference compared with a body not subjected to the action for so long a time. Temperature is of great importance but it seems possible that the time factor as it varies in practice may also play an important part in the resulting constitution and microstructure.

## Present Investigation.

With these facts in mind it was deemed worth while to make a few burns upon some quartz-clay-feldspar bodies of known composition under known conditions of time and temperature controlled as accurately as possible, with the purpose of determining by microscopic study how the increase in the time of burning affects the solution of the quartz and the development of sillimanite. This also led to a study of the manner of the formation

of sillimanite in porcelain and the presentation of a new theory as to its development during firing. Unfortunately it is impossible with present means of microscopic examination to place on an exact quantitative basis the amounts of the quartz solution and formation of sillimanite and all descriptions of the constituents of porcelain must necessarily be relative in character.

## Composition and Burning.

The body used had the following composition:

| | Per cent. |
|---|---|
| Ball clay | 10 |
| Georgia kaolin | 35 |
| Feldspar | 18 |
| Flint | 37 |
| | 100 |

The burns were carried out in the following manner: The bodies were put through a regular draw trial burn with a temperature gradient of 20° C per hour above 1150° C. Samples were taken for purposes of study from those drawn at 1290° and 1350°. These were later burned again, the temperature being raised to 1290° and 1350°, respectively, and held there for 5 hours. Samples were again taken and the burns repeated under conditions as nearly as possible like the preceding. In all, three burns were made exclusive of the draw trial firing. The total length of time the bodies were held at 1290° and 1350° was 15 hours.

## Description of the Microstructure.

**Specimen Drawn at 1290° C, Fig. 1.**—All the clay has dissociated. The outlines of the larger original clay grains still show; some are composed of sillimanite needles and others appear to consist entirely of the amorphous sillimanite. The smaller clay grains appear to have been dissolved since none can be seen. The quartz is sharp cornered and shows no evidence of solution.

**Five-hour Burn, 1290° C, Fig. 2.**—In this body the outlines of the clay grains as a rule are not so definite and they appear to have been attacked by the feldspar. Dissociation is complete. Sillimanite is somewhat better developed but, due to the small size

FIG. 1.—Draw trial, 1290° C. Sillimanite is very poorly developed and no solution of quartz has taken place, all grains possessing sharp corners. Magnification 300 diameters.

FIG. 2.—Five-hour burn, 1290° C. Sillimanite is still rather poorly developed. The quartz shows a beginning of solution by the rounding of the corners of the smallest grains. Magnification 300 diameters.

of the crystals and the comparatively low magnification used to better bring out the solution of the quartz, this does not show clearly in any of the photographs. The quartz shows slight rounding of the corners of the larger grains but this evidence of solution is more noticeable on the smaller fragments.

**Ten-hour Burn, 1290° C, Fig. 3.**—The ground-mass is composed of feldspar glass thickly filled with very minute crystals of sillimanite which are difficult to resolve except with high magnifications. Indefinite outlines of what were original clay grains can occasionally be seen but for the most part they have lost their shape entirely and have been dissolved in the feldspar

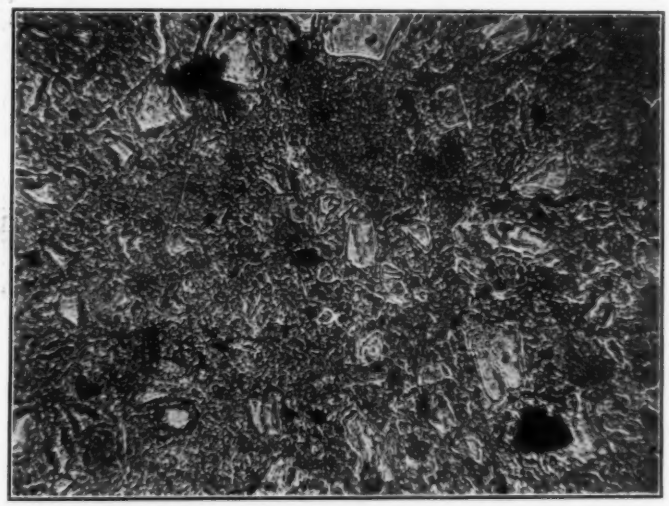


FIG. 3.—Ten-hour burn, 1290° C. The sillimanite crystals have increased in size and amount. Quartz solution is also greater. Magnification 300 diameters.

glass. When observed they are usually composed of sillimanite crystals larger than those of the ground-mass. The quartz is noticeably dissolved and each grain is surrounded by a narrow zone of glass. Even the largest grains are rounded on the corners and edges and it is particularly noticeable on the smaller ones, some of which have almost entirely disappeared.

**Fifteen-hour Burn, 1290° C, Fig. 4.**—The ground-mass is again composed of sillimanite crystals embedded in glass and they are slightly larger than those in the previous body. Groups of crystals showing the outlines of the original clay grains are very rarely met with. The condition of the quartz, the wider zone of glass and greater rounding of the fragments, gives evidence

FIG. 4.—Fifteen-hour burn, 1290° C. A great increase in the amount and size of the sillimanite crystals and the amount of quartz solution over that of the ten-hour body. Magnification 300 diameters.

of greater solution than had taken place in the ten-hour firing. A comparison of Figs. 1 and 4 gives clear evidence of the change increased length of burning will cause in porcelain bodies. This is even more strikingly brought out in the series burned at 1350° C.

**Specimen Drawn at 1350° C, Fig. 5.**—The clay grains in this body have dissociated and have lost their outlines almost entirely. The ground-mass shows glass containing very small crystals of sillimanite almost so minute as to appear amorphous. A few aggregates of fairly large crystals are present. The quartz shows noticeable solution, having slightly rounded corners and a very narrow zone of glass surrounding each grain.

FIG. 5.—Draw trial, 1350° C. Sillimanite is fairly well developed and quartz solution has begun. Magnification 300 diameters.

**Five-hour Burn, 1350° C, Fig. 6.**—This burn shows an increase in the size of the sillimanite crystals over those of the previous body. The increased solution of the quartz is also apparent

FIG. 6.—Five-hour burn, 1350° C. Note the great similarity of this body to that shown in Fig. 3. Magnification 300 diameters.

from the more pronounced rounding of the corners of the grains, the slightly wider zone of glass around them, and the fact that some of the smallest grains have almost entirely been dissolved. Comparison of this burn with that of Fig. 3 (ten hours at 1290° C) shows a striking similarity particularly in the solution of the quartz. The similarity between development of the sillimanite is also close but not quite as apparent as in the quartz solution. In the latter case ten hours' firing at a lower temperature has accomplished the work of five hours at a higher temperature.

**Ten-hour Burn, 1350° C, Fig. 7.**—The ground-mass is composed of glass with sillimanite crystals which are larger than those of the five-hour burn at 1350°. The whole section has a more

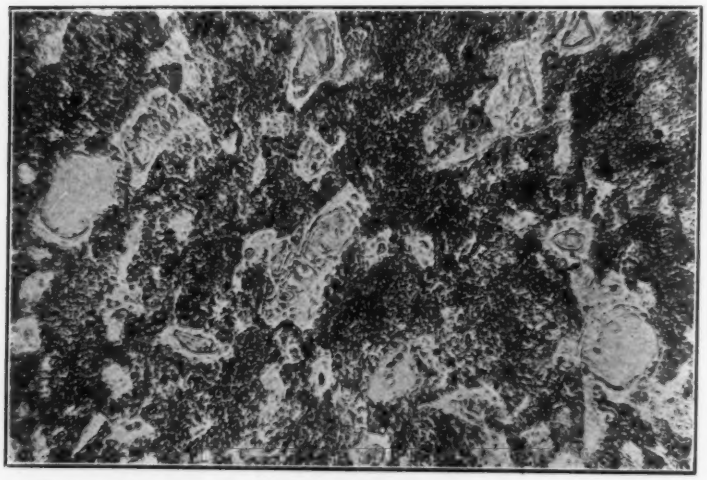


FIG. 7.—Ten-hour burn, 1350° C. The quartz is very much dissolved and much more glass is present. Magnification 300 diameters.

glassy appearance—due to the large amount of quartz which has gone into solution. A few aggregates of larger crystals of sillimanite indicate the position of original clay grains. The most striking feature is the amount of solution of the quartz. Every remaining grain, even the largest, is much corroded and surrounded by a wide zone of glass. In many instances the grain has been entirely dissolved leaving only a patch of glass in its place.

**Fifteen-hour Burn, 1350° C, Fig. 8.**—Again the sillimanite crystals show an increase in size and no trace of original clay grains remains. The quartz has almost entirely dissolved; only the remnants of the largest grains can be seen. How great this solution has been is well shown by a comparison of Figs. 9 and 10. These fields are identical with those of Figs. 5 and 8, with the exception that crossed nicols have been used to bring out more

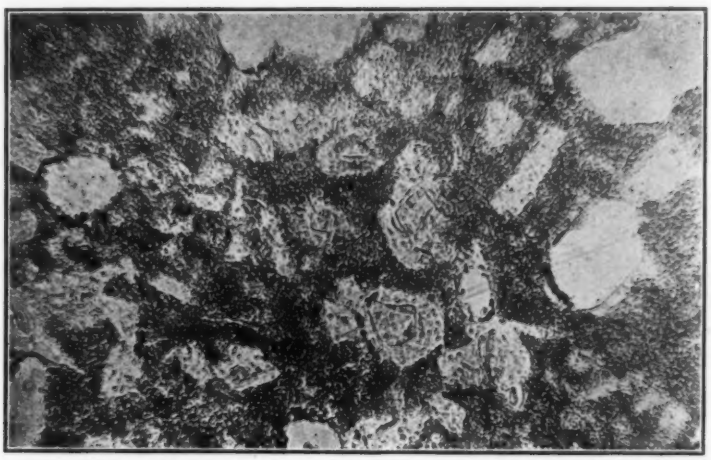


FIG. 8.—Fifteen-hour burn, 1350° C. Note the still greater increase in quartz solution. Sillimanite crystals have also increased in size. Magnification 300 diameters.

clearly the quartz. When it is considered that the body represented in Fig. 9 contained 37 per cent quartz and that this has been reduced to about 5 per cent in the body shown in Fig. 10, the difference having dissolved in the feldspar glass, the variation in microstructure which results from differences in length of burning is strikingly brought out.

Comparing the microstructure of these two series of burns, one would hardly suspect that any two of them were burned at the same temperature, except those represented in Figs. 3 and 6, and in this case it is a longer fired, lower temperature body which almost duplicates a shorter fired, higher temperature body. As a consequence it seems doubtful whether the temperature

of burning could be estimated from the microscopic examination of a porcelain.

In passing, attention is called to the fact that slight amounts of fluxes such as CaO and MgO, as shown by Riddle,[1] cause marked variations in microstructure. This reflects itself in the

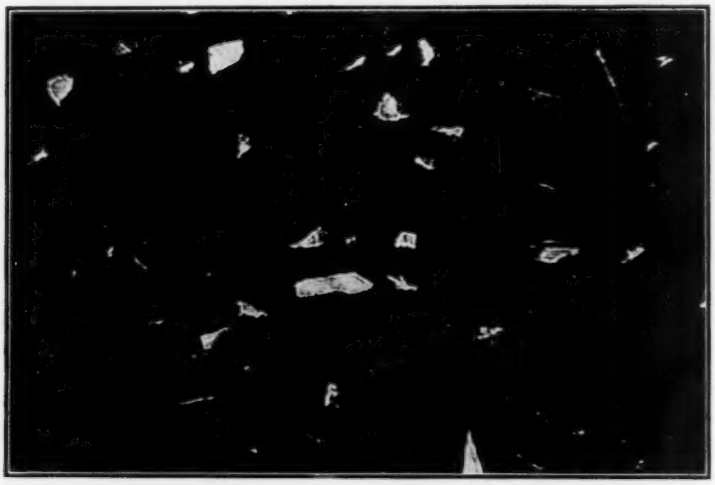


FIG. 9.—The same field as shown in Fig. 5 but taken with crossed nicols. Magnification 300 diameters.

increased translucency of the body, increasing flux producing greater translucency.

**Possible Effect on Translucency.**—Translucency of porcelain appears to have a direct relation to the proportion of glass and sillimanite in the body. Microscopically, all highly translucent bodies show glass and sillimanite as the chief components with perhaps a little quartz. It has been shown that increased length of burning results in an increase in the amount of glass and sillimanite and a decrease in the quartz. It seems possible, therefore, that the translucency of ware might be increased by firing for longer periods, particularly at temperatures upwards of 1300°.

The amount of feldspar used also probably affects the translucency, not only by providing more feldspar glass itself, but also

[1] Private communication.

FIG. 10.—The same field as shown in Fig. 8 but taken with crossed nicols. This serves to show the great amount of quartz which has dissolved during the fifteen hours of burning although the temperature remained constant. Magnification 300 diameters.

more of a medium for faster solution of the clay and crystallization of sillimanite and solution of the quartz.

### The Effect of Ordinary Differences in Time of Burning upon the Microstructure.

The preceding pages have shown that time markedly affects the constitution and microstructure of porcelain. The question remains, whether ordinary differences in burning practice are sufficient to cause differences in microstructure.

Ordinarily this depends on two factors—the final temperature to be attained and the size of the kiln. Obviously, the higher the final temperature, the longer will it take to reach that temperature, using the same gradient in each case.

According to European practice, in small kilns the burns may range from 18 to 28 hours, in large kilns from 30 to 45 or 54 hours. In Fig. 11 are shown two heating and cooling curves of commercial kilns both fired to the same temperature—about 1320–1330°, the smaller requiring 52 hours and the larger 59 hours.

It is in the vicinity of 1250° that the microstructure of porcelain bodies of ordinary composition begins to show phenomena other than the melting of the feldspar and the dissociation of the clay into amorphous forms of silica and sillimanite. At this temperature crystalline sillimanite appears in small amounts and at slightly higher temperatures solution of the quartz starts.

Considering the points on the diagram where the heating and cooling curves cross the 1250° ordinate, it is apparent that approximately 21 hours have elapsed in the case of the longer burn from the time 1250° was passed on the upward curve to the time

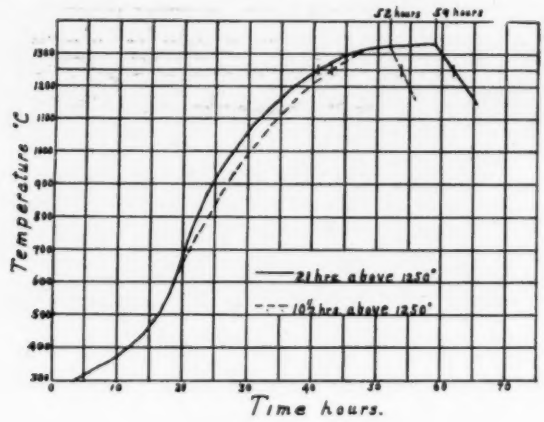



FIG. 11.

it was again reached on the downward curve. Similarly in the second case the elapsed time was about $10^1/_2$ hours, a difference between the two of about $10^1/_2$ hours. During this time the body was in what may be termed the zone of reaction and was, therefore, undergoing changes in structure and constitution. This action while not constant in velocity but varying with the temperature is nevertheless continuous whether the temperature is rising or falling. On account of the flattening of the tops of the curves, the average temperature of the body while in this zone of reaction is probably not far from 1300°. In view of what was found in bodies held at constant temperatures it would not be surprising to find that porcelains, burned according to such

curves as those shown in Fig. 11, exhibited noticeable differences in structure.

Figures 12 and 13 show the microstructure of two porcelains burned in actual commercial practice according to these curves. Each is slightly shorter, that of Fig. 12 requiring 49 hours while that of Fig. 13 required 56 hours, a probable difference in elapsed time of about 8 hours.

The porcelain shown in Fig. 12 shows almost no solution of the quartz. The sillimanite is nearly all present in a crystalline

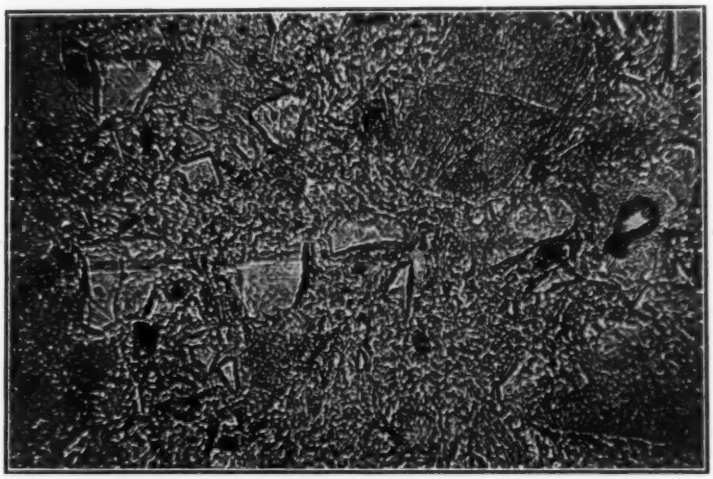


FIG. 12.—The quartz grains are sharp and angular for the most part and the sillimanite is usually found in very minutely crystalline aggregates as shown in the upper right hand corner. Magnification 300 diameters.

state but occurs usually in groups of very minute crystals. The fluxing action of the feldspar has not been marked since the outlines of the original clay grains are frequently well preserved and only small amounts of well crystallized sillimanite are present. The porcelain of the longer burn (Fig. 13) shows greater solution of the quartz as is evident from the rounding of a greater number of the quartz grains. The frequency of aggregates of very finely crystalline sillimanite has become less and more groups of well developed crystals embedded in the feldspar glass can be ob-

served. The contrast between the two bodies seems to be sufficient evidence that the difference in length of burning in practice actually does produce important differences in structure and that the estimation of the temperature should be considered rather doubtful.

### The Formation of Sillimanite in Porcelain.

In the study of porcelain the question naturally arises—how is the sillimanite formed? Since no sillimanite enters into the

FIG. 13.—In this longer-burn specimen the quartz grains are more generally rounded showing the effects of solution while the sillimanite is more frequently present as large, well-developed crystals in the feldspar glass. A group of these appears near the top of the photograph. Magnification 300 diameters.

composition of the original mix, it must form either through the breaking down of one or more of the constituents of the mix or by a re-combination in some manner of the elements composing it.

Microscopic examination of porcelain reveals the fact that there are really two types of sillimanite present. The first type is shown in Fig. 14[1] and is frequently characterized by a fibrous

[1] Figs. 14 and 15 have been taken from Bur. Standards, *Tech. Paper* 80, by A. A. Klein.

appearance brought about by long, slender crystals orienting themselves parallel to each other, or it may take the form of confused aggregates of almost sub-microscopic amorphous-like grains, or of small, interlocking, poorly formed crystals. Sometimes the outlines of the original clay fragments are retained although the feldspar has usually attacked them and rounded the corners. There seems to be little doubt that this type has been developed by the direct dissociation and molecular change of the clay under

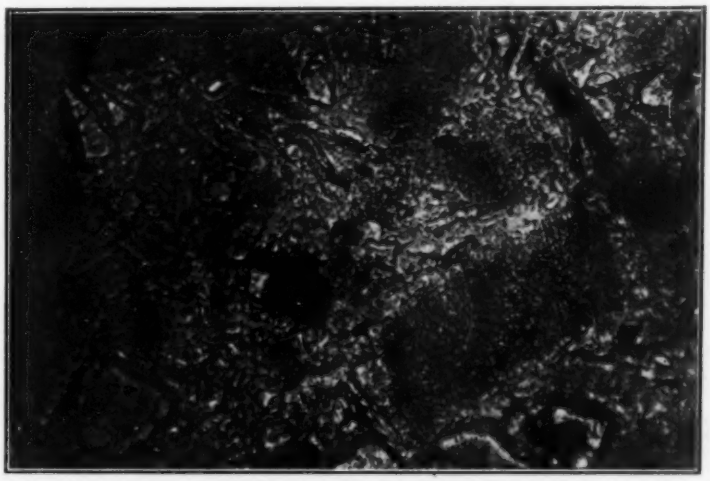


FIG. 14.—In the upper central part are two aggregates of apparently amorphous sillimanite, toward the right hand margin is a fibrous aggregate, and in the lower right hand corner is a group of very small, interlocking sillimanite crystals. Magnification 380 diameters.

the influence of heat alone into amorphous forms of silica and sillimanite. If the action of the heat ceases, the sillimanite remains amorphous, but if continued or increased, the amorphous grains undoubtedly coalesce and gradually form crystalline aggregates in the same manner as does amorphous CaO under the influence of heat at a temperature of 1300–1400° C, 1000° below its melting point.

The second type is shown in Fig. 15 and is represented by definite, well-formed crystals embedded in the feldspar glass.

Their position and development give strong indications that they have crystallized out of solution. These crystals are most abundant in high-fired or high feldspar bodies or may be found projecting from a body into the glaze where molecular mobility is easy and great. They are also observed in long-fired, medium temperature bodies. These crystals represent what may be termed the end product of sillimanite crystallization since they appear to be the only product besides glass in hard porcelain.

Investigators have held different views regarding the formation of this type of sillimanite—some that it is due to devitrifica-

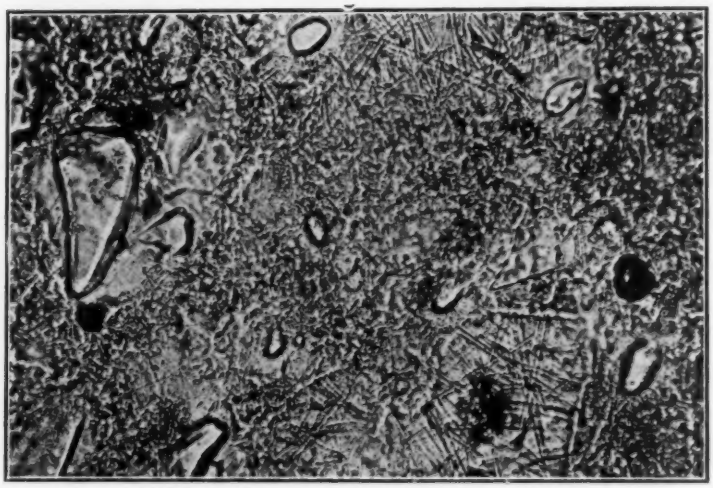


FIG. 15.—In the upper right and lower left hand corners are seen many large, well-developed sillimanite crystals embedded in feldspar glass. Magnification 380 diameters.

tion and others to molecular change of the clay. In order to arrive at some conclusion concerning this, fusions of feldspar and clay in various proportions were made in unglazed porcelain crucibles in a small surface combustion furnace. The fusions were held at a temperature of 1400° for three hours and then quenched by dropping into water. The compositions of the fusions were as follows:

| Feldspar. | Clay. |
|---|---|
| 90 | 10 |
| 80 | 20 |
| 70 | 30 |
| 60 | 40 |
| 50 | 50 |

The clay in each case was composed of one part of Kentucky ball clay and four parts of North Carolina kaolin. Maine feldspar was used and one fusion of this alone was made at the same time.

Examination of the fusions after quenching showed that the feldspar containing no clay had melted to a clear glass with a refractive index of 1.485 ±0.003. The small amount of original quartz had practically all disappeared as was the case in all the other bodies. No other components could be found. The body containing 10 per cent clay was composed almost entirely of a glass with an index of 1.490 ±0.003, slightly higher than that of the pure feldspar glass. Besides residual quartz there was a very small amount of minute sillimanite crystals. These usually occurred in small aggregates with individual crystals distinctly separated from each other. Their outline was definite in all cases although the end terminations tended to be rounded rather than sharp. With 20 per cent clay the glass increased its index slightly to 1.493 ±0.003. The amount of sillimanite crystals was slightly greater than in the previous body and their general appearance was the same although occasionally a few larger and more definitely terminated crystals were present. At 30 per cent clay, the refractive index of the glass was identical with that of the previous body. The amount of sillimanite crystals had increased but their general appearance was the same. The same held true for the bodies with 40 and 50 per cent clay; the refractive index of the glass remained the same and the sillimanite crystals showed a steady increase in amount. No undissolved clay was present in any of the foregoing bodies.

Following this, two mixtures of feldspar containing 20 per cent and 30 per cent clay were fired to cone 14 in a large downdraft kiln along with some ware and allowed to cool down with the kiln. Subsequent examination of these bodies showed that

they differed in no respect from the bodies which had been quenched. The refractive index of the glass was 1.493 ± 0.003, the crystals of sillimanite were the same size, and, as far as could be judged, were present in the same amounts as in the respective quenched bodies. Neither of these two fusions showed large well developed needles of sillimanite as would be expected if the sillimanite were formed by devitrification of the feldspar glass on slow cooling. Since we find the development of the crystals the same in both quenched and slowly cooled bodies, the obvious conclusion must be that the sillimanite forms as such at the temperature of the porcelain kiln and not through devitrification on cooling. If the latter were true, we would expect to find an increase in the amount of sillimanite crystals and probably an increase in their size and perfection of development under slow cooling. Furthermore, we would expect the feldspar glass to show a somewhat lower index of refraction—due to its loss of $Al_2O_3$ through increased sillimanite crystallization.

In view of the facts as shown in these experiments the conclusion must be that the sillimanite in the feldspar glass and probably also the well developed sillimanite crystals in porcelain are formed at porcelain kiln temperatures and are not due to devitrification.

Exactly how the crystallization of the sillimanite takes place is not easily determinable. Zoellner[1] has shown that feldspar will dissolve 3.5 per cent $Al_2O_3$, 14 per cent clay, and 60–70 per cent quartz, the relations not being changed in the presence of more than two components. Referring to the feldspar-clay series described, it is apparent that the index of refraction of the feldspar has reached its maximum at a point between 10 and 20 per cent of clay content and that beyond 20 per cent the only change is an increase in the amount of sillimanite formed. Once the feldspar glass has become saturated with regard to $Al_2O_3$, conditions become very favorable for crystallization of sillimanite, which might take place in several ways. Kiln temperatures vary over a range of several degrees and a slight drop in temperature would very probably result in the beginning of crystallization. It has been previously pointed out that clay

[1] *Sprechsaal*, **41**, 471–73, 533–36.

passes into an amorphous phase of sillimanite and later into a crystalline phase. When the crystalline sillimanite has once been formed in this manner in a saturated solution it may immediately serve as a nucleus for further crystallization. After crystallization has started there would be four constituents present—saturated feldspar glass, amorphous sillimanite, silica resulting from the breakdown of the clay, and crystallized sillimanite. It is commonly known that if into a saturated solution, out of which small crystals are crystallizing, a large crystal of the same kind is introduced, the large crystal will under the same conditions continue to grow at the expense of the smaller ones until finally they may have disappeared completely and have been recrystallized as part of the large crystal. If several large crystals are introduced instead of one the result is again the same number of still larger crystals. Amorphous bodies are also more soluble than crystalline bodies of the same chemical composition. Therefore, where there are present saturated feldspar glass, amorphous sillimanite and a little crystallized sillimanite, it appears quite probable that the amorphous sillimanite passes into solution in the feldspar glass just as fast as aluminium silicate passes into the crystalline state and crystallizes as sillimanite, around nuclear crystals which were formed either by fluctuations in temperature or by coalescence of amorphous into crystalline sillimanite. While conditions remain reasonably constant the reaction would proceed in the foregoing manner until, if firing does not cease, all amorphous sillimanite would be transformed into saturated feldspar glass and crystallized sillimanite.

This is precisely the condition found in feldspar-clay mixtures or in long- or high-fired porcelain except that in the latter two cases some undissolved quartz may remain. It seems quite probable, therefore, that sillimanite forms as well-defined crystals in porcelain at kiln temperatures and not by devitrification.

The size of the crystals developed appears to be influenced by three factors—the amount of feldspar or other fluxes present, the mobility of the feldspar as affected by the temperature of firing, and the length of time of firing. It is hoped that further work will throw more light on these factors.

**Summary.**

Petrographic microscopic examination shows that quite dissimilar bodies can be produced by holding porcelain at a constant temperature for lengths of time which lie within the variations of commercial practice, the clay passing into amorphous silica and sillimanite which in turn passes into crystallized sillimanite. The solution of the quartz takes place at the same time. The difference in structure becomes more marked, the higher the burning temperature.

The longer the burning at a constant temperature, the greater is the amount of sillimanite formed, the larger and better developed do the crystals become, and the greater is the amount of quartz dissolved by the feldspar.

Bodies fired for longer periods at lower temperatures have been produced, which simulate very closely those fired at higher temperatures for shorter periods.

Long burning tends to produce increasing amounts of glass and sillimanite and, therefore, probably increases the translucency.

Sillimanite crystals form; first, by a gradual passage from the amorphous to crystalline state without the aid of a flux; second, with the aid of feldspar as a flux, they form in well developed crystals in the feldspar glass at kiln temperatures through solution and recrystallization of amorphous sillimanite.

In view of all the preceding facts it does not appear that the temperature of burning of porcelain bodies can be predicted from a petrographic microscopic study without at least some knowledge of composition and length of firing.

The author here takes pleasure in expressing his sincere appreciation to Mr. A. V. Bleininger, Mr. F. H. Riddle, and Mr. J. W. Wright for aid and advice during the progress of the work.

# THE DESIGNING OF FACTORY LAYOUTS FOR THE CLAY INDUSTRIES.

By T. W. Garve, Columbus, Ohio.

Technical designing is an art as well as a science. Any design or construction which has to perform a certain duty during its time of usefulness is a creation, but only worthy of that name if the most effective solution has been found, and the most effective is usually the simplest. Effectiveness, simplicity and ornateness are fundamentals for the factory designer and their importance is in the order named.

The designing of public buildings and dwellings has always been the work of the architect, but when it came to the design and construction of skyscrapers, with the abundant use of steel and reinforced concrete and power equipment, the work had to be subdivided. The architect first works out the plan, then the engineer designs the frame, and finally the artist embellishes the structure. In designing factories the engineer's work is of chief importance.

Housing is the sole purpose of the building, and the engineer's work, though important, is secondary. He first places the machinery in every detail and then adds the structure to support and house it. The architect and artist are not essential, but in many instances it is to be regretted that the latter is not consulted.

The architect's work is decidedly varied but his problem is a single one, namely, housing. The engineer's work is very different; he is dealing with manufacturing processes and must be an expert in each process for which he designs a factory, or he must call to his aid those who are experts to work out the details of each problem, leaving for him the general mechanical features and final assembly of the factory as a whole.

A machine is usually built first as a trial, then corrected and improved upon, and often completely remodeled and rebuilt before it is turned out in a large number as a type. A factory,

however, cannot be corrected so easily. Buildings cannot be shifted nor can foundations be torn out; there is, besides, too much money invested in a manufacturing plant to permit of experimenting afterwards; it has to be *right in the first place.* How many clayworking plants have been right in the *first* place?

Of course, a clayworking plant is not a shoe factory or an automobile factory; there are no two clayworking plants alike—hence the very essential requirement of the designing engineer is to be familiar with the branches of clayworking and to be broad enough to study the proposition in question from every angle.

We cannot do better than quote from Day's "Industrial Plants,"[1] as follows:

> "It will be evident that during the limited period needed for the designing of a new plant, almost every branch of engineering may be called into play. Those for whom the new plant is being built must be counted upon to dictate primary requirements, but in the majority of cases their experience should be supplemented by the broader knowledge of others.
>
> For the need of a better term 'industrial engineering' has been quite generally adopted as the name for the professional service rendered by independent engineers engaged upon such work.
>
> The industrial engineer coördinates the mass of technical notes turned in to him by the various engineers engaged upon his work, and on account of his intimate acquaintance with his client's needs, aims, and resources, he is able to consider the conclusions presented from a broad standpoint that is wholly unknown to the individual workers. He is to remember constantly that it is the final result that measures the usefulness of his efforts, and that it is absolutely immaterial from what source a given suggestion may come. As a general proposition, complete plans and specifications, covering all features entering into building structures, should be prepared prior to soliciting bids; but this work must, of course, be done by men thoroughly conversant with all available standards and the usual practices adopted in shops."

Any clayworking proposition should be investigated very thoroughly before a preliminary plant layout is studied and worked out. The kind and quantity of ware to be made, the physical conditions of the clay, and local conditions and requirements will determine the kind of machinery to be used and the type of dryer and type of kilns to be adopted. There is a great variety of machinery of different types and makes on the market

[1] "Industrial Plants," by Charles Day, The Engineering Magazine, New York, N. Y.

and it is often difficult to select the equipment best suited. The location of the plant, market conditions, quantity of clay and the capital available will be factors in determining the kind of building materials to be used (whether brick, steel, lumber, concrete, kind of roofing, etc.).

We have heard much in these days about conservation of fuel and to this end kiln and boiler furnaces and methods of firing have been improved. How much fuel, however, is daily being wasted in a factory where the routing is not the shortest possible, or where conveyors are too long, elevators too high, and where power transmitting appliances of relatively low efficiency are abundantly in evidence. We quote Lovejoy from "Economies in Brickyard Construction and Operation" as follows:

> "From the power house we go into the factory and find short drives with belts drawn up by stretchers, unnecessary countershafting, and both line and countershafting out of line, crooked and badly wobbling, top pulls on belts and unnecessarily crossed belts—the list is too long to enumerate, but everything dragging and eating up boiler fuel."

In this paper we have attempted to point out some essential, general features in clay working factories without, however, taking up variations in each type, the discussion of which would be endless.

**Clay Haulage.**—The distance the clay is to be hauled should be as short as possible. Whether the plant is to be built close to town or close to mine or clay bank is often a local consideration and cannot be stated definitely one way or the other; we would have to know the situation of the market, the railroad, and other local peculiarities such as fuel, labor, water, housing, transportation, etc.

If a mine shaft is used close to the plant, the clay or shale should be delivered from it at the highest point of the factory in order to eliminate further elevating as far as possible. Gravity haul from the bank is recommendable if the site of the plant and the elevation of the bank will permit. Most often the clay is to be elevated and a winding drum or steam hoist is used at the highest point of the incline. Since clay dump-cars are made of the bottom, side, and end dump types, there is much latitude

in conveniently arranging the clay storage and clay feeder or any other preparing machine to be fed. Any incline should be steep enough to allow the empty cars to return with dragging cable. If the clay or shale is to be hauled in by wagons or railroad cars, it may be advisable to build up a slight incline, by earth filling or by trestle, to avoid a great depth below ground for clay hoppers, feeders, or elevator tail ends.

**Clay Storage.**—Raw clay is stored for the purpose of sufficient supply during winter or during bad weather; to help over any breakdown at the mine or bank; to secure a better and more uniform mixture; and to improve the working condition of the clay and quality of the ware.

Clay storage equipment should be an independent feature of the plant that can be in use continuously or intermittently as conditions require so that all unnecessary rehandling is avoided. It should face the clay bank and later extension should be possible.

Ground clay storage within the factory is an essential feature to insure continuity so that the consequences of a breakdown, or any irregularity in supply of clay, will be checked at the bin and not be felt throughout the succeeding manufacturing processes of the plant.

**Machinery Building.**—One end of this building, where the clay enters, should be in touch with the clay storage building and the other end close to the dryer (or kilns). The shortest possible routing and as automatic as is practical is to be devised avoiding, however, a too elaborate system of conveying machinery. If it can be worked out it is best to do all the elevating in the first place and then to let the clay pass from machine to machine by gravity. If two or more sets of preparing machines are used, provision should be made for a certain elasticity in the arrangement by which an exchange of duty can be accomplished. This applies especially to large plants which turn out two or more kinds of ware and where a corresponding number of types of preparing machinery is to be installed. Here the grinding or preparing outfit for one kind of ware may be called upon to do duty for the other kind of ware and vice versa. Other demands may arise later during the manufacture and development of the

product and there are often quite a number of eventualities which have to be taken into consideration in designing the machinery layout and building.

If electric motors are employed in power transmission they should be driven by belt to machinery and by belt or silent chain to shafting, avoiding gears. The shafting should be well balanced and placed so that the drives are of proper length and the lower side of every belt is pulling—avoiding bevel gears and cross belts as much as possible. A quarter twist belt, if installed properly, is not objectionable for light duty, especially if it enables a more satisfactory arrangement of machinery.

There should be ample space around each machine, without waste, although too much is better than not enough. There should be sufficient head room above each machine for a chain block and suitable structure to carry it.

The light question is an important consideration often overlooked or neglected in clay working plants.

Avoid deep pits if possible and always keep above ground water level with the bottom of any pit.

Line shafting should be carried on independent concrete or brick piers and all machinery platforms should be sufficiently heavy and well braced to reduce building vibrations to a minimum.

The conveying machinery usually employed in clay plants consists of troughing belt conveyors and belt bucket elevators. Sticky or wet clays are very difficult to convey and elevate, even on inclined elevators with open buckets or flights, and should be avoided if possible.

If depth or elevation can be had, it is advisable to use a gravity hopper below the dry pan instead of scrapers—thus lessening maintenance cost and power consumption.

The dry grinding plant should always be separated from the rest of the factory by a dust-proof wall or partition. Dust is harmful to human lungs as well as to bearings and will cause belts to slip. Shafts can pass through such partitions but belts should not go through. Modern factories sometimes encase the grinding machines and remove the dust by fan suction.

Finally, provision should be made for expansion in every factor of the plant for future increase in capacity.

**Power House.**—The power equipment should be independently enclosed in a dust and fireproof building or rooms. If belted to a line shaft it should be so located as to balance the load, or in any event, there should be no material extension of the line shaft to connect with the power drive and an end connection should be

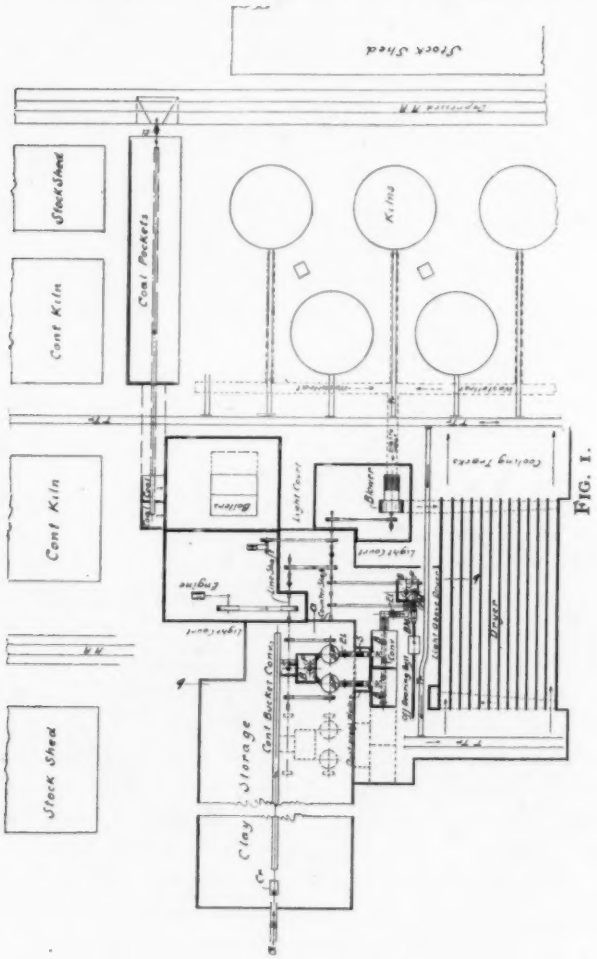



FIG. 1.

that nearest the heaviest load. Where steam is used for drying, the equipment for such applications should be close to the power plant in order to keep down the cost of installation, to conserve the heat, and where it will be under the watchful eye of the power operator, bearing in mind, of course, that the position of the dryer relative to the movement of the ware is of first importance.

There should always be a surplus boiler, enough room left

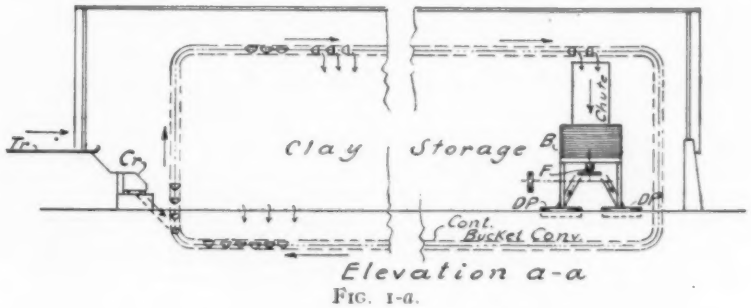



FIG. 1-*a*.

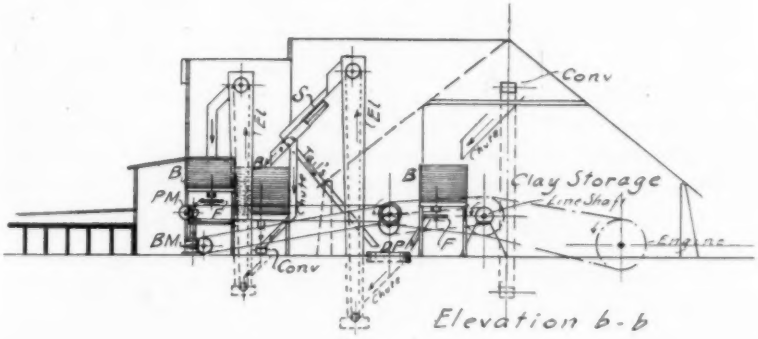



FIG. 1-*b*.

at the rear for removal and cleaning of boiler tubes, and space at the front to allow a sufficient coal supply close to the furnaces. The boiler house should be so located that fuel can be delivered to the boilers in a convenient and economical manner.

There should be sufficient space between engine cylinder and building wall to allow the removal of piston and rod.

The power house should be fireproof and provision made for future extension.

**Dryer.**—The receiving end should be close to the machinery delivery and the cooling end should face the kilns. At the end of the dryer toward the kilns cooling space or cooling tracks should be provided. The closer the dryer is to the kilns the shorter

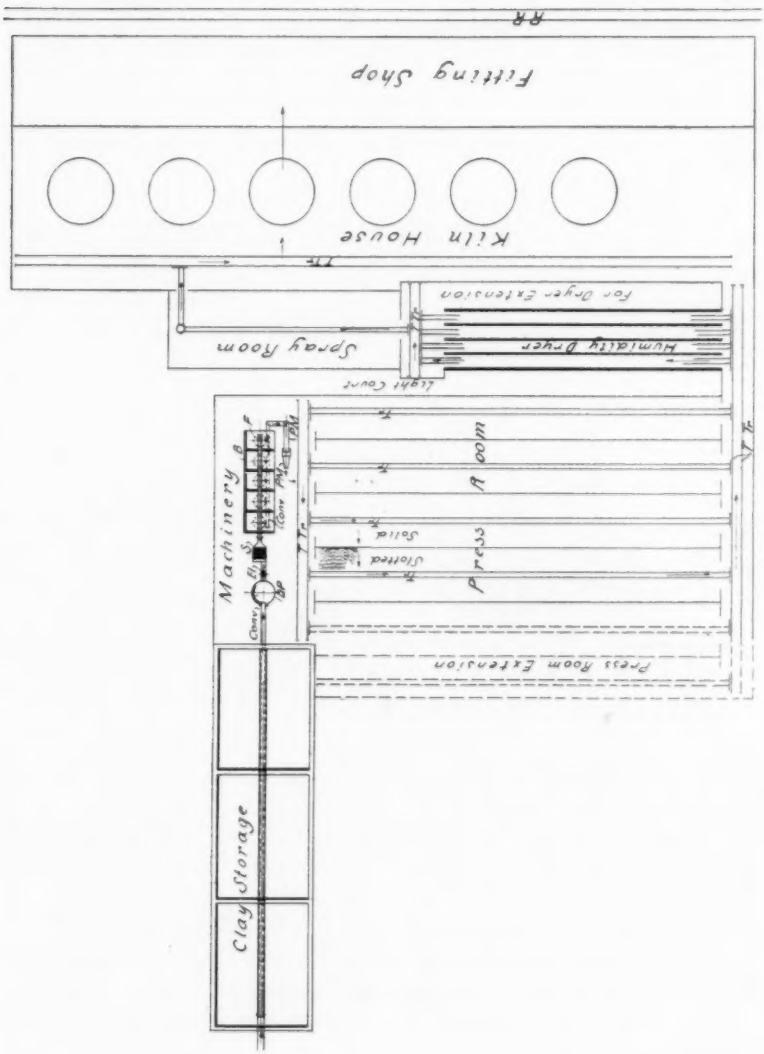



FIG. 2.

the haulage of the dried ware and the shorter the waste heat duct from the kilns, if such a system is employed.

It is imperative that the dryer be fireproof throughout.

**Kilns.**—Convenient car switching for the ware and convenient delivery and distribution of coal must be possible. The kilns should, without waste of space, stretch along a stock shed and railroad switch.

As an illustration we have sketched the three clay working plants shown in Figs. 1, 2 and 3. For the sake of clearness it was deemed advisable to abbreviate some of the lettering as follows:

| | | | |
|---|---|---|---|
| B | Bin | B. M | Brick machine |
| Cr | Crusher | D. P | Dry pan |
| Conv | Conveyor | S | Screen |
| El | Elevator | Tr | Track |
| F | Feeder | T. Tr | Transfer track |
| P. M | Pug mill | R. R | Railroad |

**Building Brick Plant** (Fig. 1).—The clay storage building can be extended to any desired capacity towards the clay intake end. The crushed clay or shale from the crusher is delivered by a short chute to a continuous bucket conveyor which can supply either the storage building or the pan bin directly; it can also take the stored shale by means of the underground strand up to the pan bin. The screened clay from the pan can chute to storage bins at the bottom of which a belt conveyor is operating towards an elevator at the pug mill bin. If these storage bins are filled, the screened clay can chute down directly to the belt conveyor mentioned. Additional pans and additional storage bins for ground shale can be built without any other change in the arrangement (shown dotted).

The engine is running over, the drive is located in the middle of the line shaft between equal loads and all belts are pulling at the under side.

The dryer blower is driven from the main engine during the day and by a separate motor or gas-engine during the night. The necessary clutch coupling in the counter shaft is provided for.

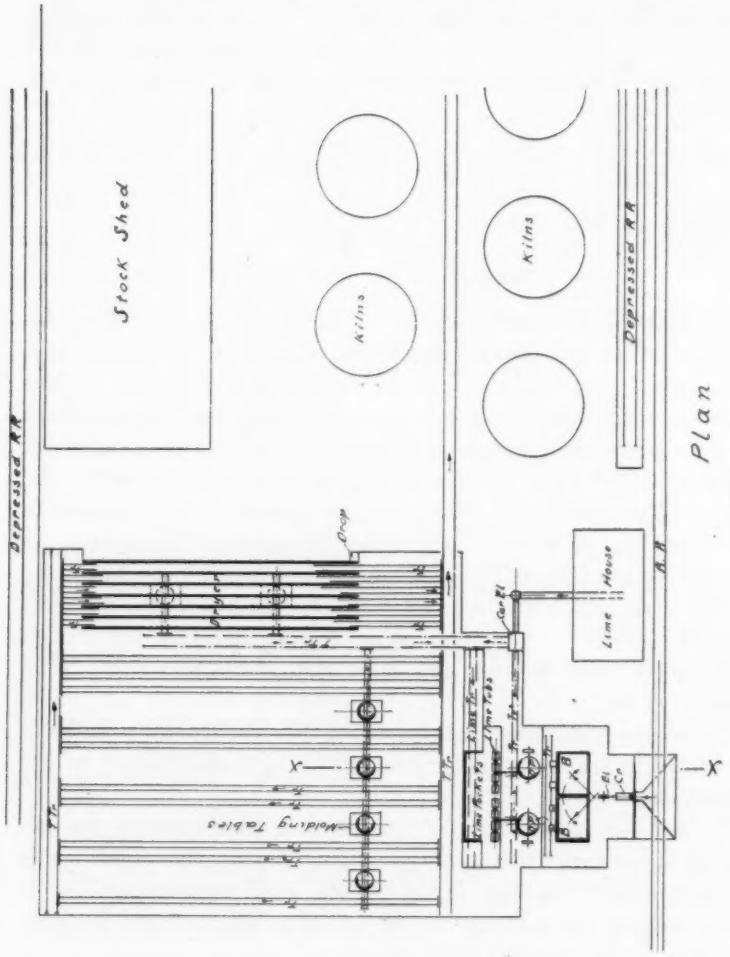
The loading track along the off bearing belt is short, straight, and close to the intake end of the dryer.

FIG. 2.

The waste heat intake to the blower is located very near the center of the periodic kilns.

Dryer, blower house, and power station are built with independent brick walls and good light is obtainable. The machinery building will receive its light from two light courts, through windows above the dryer and elevator monitor.

The transfer track from the dryer stretches along one side of the




Plan

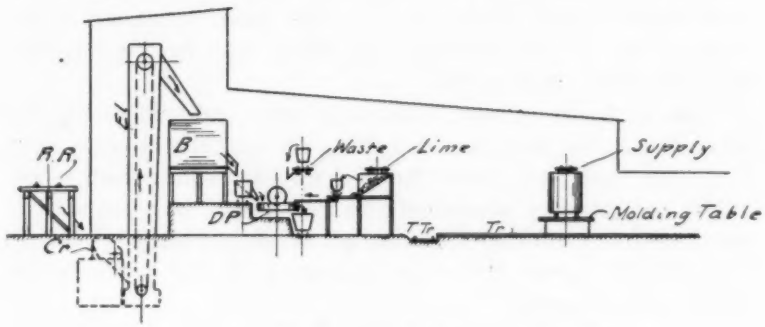
FIG. 3.

periodic kilns and passes between the two rows of tunnels or chambers of the continuous kiln. Electric transfer cars can be used for operating along these kilns. The intake tracks to the kilns are straight and short.

There are two railroad switches and three stock sheds. Coal is being delivered close to the kilns and boilers.

The dryer can be extended and also the kilns.

It is often difficult to find a satisfactory solution for a machinery layout with the application of a steam engine with dependent




Elevation X-X

FIG. 3-a.

shafting and belting, especially for a plant of large capacity. With the application of electric power we have much more latitude in the machinery arrangement and less difficulty in finding a satisfactory solution.

**Terra Cotta Plant** (Fig. 2).—The clays are dumped by car or conveying machinery into storage bins and from there taken by a conveyor and elevator to a dry pan. The ground clay is screened and delivered into small bins for each clay with a feeder at the bottom of each bin and a belt conveyor alongside the feeders to carry the clay to an open-top pug mill, from which it passes down to a closed top or conical pug mill.

The clay is now ready for the molders and is taken to the so-called press building by trucks on wheelways or by cars on tracks

as shown. The clay taken down the first track in the press building is here made into ware which is then moved over towards the second track to remain for a while on a slotted floor, with a few steam pipes below for partial drying, before the ware is picked up from the second track and taken into the humidity tunnel dryer, or the ware can be run directly to the dryer. Over a part of the press room is a second story for storage of molds and for the drafting room.

From the dryer the ware passes through the so-called spray room for the particular coating. The grinding and preparation room (pebble mills, tanks, etc.) for the glazes is located in the second story of this building; this would also be a good place for a laboratory and an office.

Close to the spray room is the kiln house and next to the kiln house the fitting shop and then the railroad. Terra cotta work is, for the most part, special work to suit the requirements of the orders and made up accordingly, hence we have no stock shed or stock room but a fitting shop instead, before shipment is made.

A separate power house for generating electric power is not shown in the drawing.

**Silica Brick Plant** (Fig. 3).—From the railroad car, on a low trestle, the quartzite is dumped into a pocket in front of a jaw crusher, then crushed, elevated and stored. It is drawn from the bins and run to the pans. From the other side the pans are supplied with the necessary lime. The lime slip is piped down from a row of lime tubs especially made for this purpose (Fig. 3-*a*). Each tub has its independent bottom discharge above the same trough. To one side of these tubs are open lime pockets supplied with lime from cars on the track above. The lime is brought in here by cars on tracks and through an elevator from the lime house near the railroad.

The prepared clay-lime mixture is dumped into cars below the pans and taken to the elevator and then to the molding room by discharging them over cylindrical containers open at the bottom in the center of each molding table. The molding tables are at one end of the room to allow for long tracks at the other end in order to have the ware lose some of its water before it enters the

tunnel dryer. There are also molding tables above the dryer for larger wares which require slow drying.

The car and track shown in elevation above the pans are for the return of all waste to the pans. The lower loading and transfer tracks and the previous elevator are used for this purpose also. Note the same elevation of the three upper tracks (waste, lime, and supply).

# BEHAVIOR UNDER BRASS FOUNDRY PRACTICE OF CRUCIBLES CONTAINING CEYLON, CANADIAN AND ALABAMA GRAPHITES.[1]

By R. T. Stull.

The life of a graphite crucible depends upon so many factors that it is difficult, if not impossible, to obtain accurate data from which consistent conclusions can be drawn. The best that can be done is to test a large number of crucibles under a set of conditions as nearly constant as possible and to take a fair average of the results.

The composition of the crucible, the conditions surrounding its manufacture, its size and shape, and its use and misuse in the foundry, all contribute to determine the length of life of the crucible.

It is not difficult to get coöperation with foundries in testing crucibles, but it is difficult and even impossible to educate the workmen up to the point where they can understand the importance of exercising reasonable care and accuracy and to take more than a passive interest in the work. This is especially true in foundries where the workmen are paid on a tonnage output basis, because it matters not to them whether one or ten crucibles are required to produce a definite quantity of metal.

It requires approximately a month's time to make a crucible of No. 60 size or larger and after the crucible arrives at the foundry it requires from three to four weeks to dry it thoroughly at a temperature of from 100° to 110° C.

Thoroughly dried crucibles give greater service than those which are imperfectly dried, as has been pointed out by Gillett[2] and Bleininger.[3] After the crucibles have been taken from the kiln they

[1] By permission of the Director, U. S. Bureau of Mines.

[2] H. W. Gillett, "Brass Foundry Practice," U. S. Bureau of Mines, *Bull.* **73**, p. 161, June, 1916.

[3] A. V. Bleininger, "Notes on the Crucible Situation," *The Clay Worker*, p. 531, Dec., 1917.

may take up as much as 5 per cent hygroscopic moisture and its expulsion in the drier is slow. In order that the tests may be comparable, the crucibles should remain in the drier about one month before being placed in the melting furnace. Some of the crucibles tested in the following work remained in the drier for only $3^1/_2$ days, while others received 29 and 30 days' drying.

Inasmuch as it requires a month to make a crucible which should receive a month's drying treatment before it is tested, and may require two weeks' time in transportation between factory and foundry, the process of testing crucibles is slow and as the size of crucibles tested retails at from $7.00 to $10.00 apiece, the process is also rather expensive when a large number of crucibles is tested.

The number of crucibles tested is altogether insufficient to permit drawing definite conclusions and the conditions under which different groups were tested varied so, that only conclusions of a more or less speculative nature can be drawn for the different groups and from different members in their respective groups. The work has just begun, and so far as it has progressed, may be considered as preliminary.

## Crucibles Tested.

Four series of crucibles[1] of three different sizes, No. 60, No. 70 and No. 80D, have been made. The crucibles were tested in two different brass foundries designated herein as foundries No. 1 and No. 2.

Foundry No. 1 operates thirty-six natural-draft pit furnaces using a No. 70-size crucible. The furnaces are operated for a period of 12 hours per day on coke which must be clean, hard, and low in sulphur. In the morning the fire is kindled on the grates and a layer of coke placed on top. The crucible is set on the fuel bed and a mixture of coarse and fine coke packed between the outside of the crucible and the furnace lining. When the crucible reaches a red heat, a ring made from the upper half of a discarded crucible is placed on top of the crucible in order

[1] These crucibles were made by the Vesuvius Crucible Co., of Swissvale, Pa., through the kindness of Mr. F. L. Arensberg, President, to whom the Bureau of Mines is greatly indebted for his interest and generous coöperation.

to prevent notching and the charge is then introduced. Usually it requires from 90 to 120 minutes to melt and heat the charge to the desired pouring temperature.

When the metal is ready to pour, the crucible is removed, by well fashioned tongs of the grab type operated by a chain block, and lowered into a shank and carried to the molds and poured. After pouring, the crucible is immediately returned to the furnace for recharging. The operation requires about six minutes and during that time the crucible cools down to a dull red.

Foundry No. 2 operates sixty-four natural-draft, coke-fired pit furnaces on No. 80-size crucibles. The operations are carried out in a similar manner to those of foundry No. 1, except that no protecting ring is used and the tops of the crucibles are considerably worn down during charging. In foundry No. 1 as much care in handling the crucibles was exercised as maximum production would permit. Rough handling seemed to be the rule in foundry No. 2 and the crucibles were used with what might be called lavishness.

The gripping portion of the tongs was narrow and when undue pressure was applied cut into the crucible and was responsible for shortening its life. After the crucible was carried to the molds in the tongs and poured, it was loosened from the tongs and dragged back across the floor and placed in the furnace for recharging.

Of the crucibles tested, the first two series contained Ceylon and Canadian graphites, and the third and fourth series contained Ceylon and Alabama graphites. In curtailing imports on foreign graphite in order to save ship tonnage, the crucible manufacturers were restricted to the use of 25 per cent American graphite. The following tests were made in order to obtain data relative to the effect upon the life of the crucible of substituting flake graphite for the Ceylon graphite.

### Series 1.

The first series consisted of seven members marked Nos. 50 to 56 inclusive. Nos. 50, 51, 52 and 53 represent mixtures of Ceylon and Canadian graphites up to the 25 per cent require-

ments. Nos. 54, 55 and 56 contained 25 per cent Canadian graphite but with variable clay content. The compositions of the crucible bodies are given in Table 1.

TABLE 1.—COMPOSITIONS, SERIES 1.

| Mark. | No. 50. | No. 51. | No. 52. | No. 53. | No. 54. | No. 55. | No. 56. |
|---|---|---|---|---|---|---|---|
| Ceylon graphite | 55.0 | 49.5 | 45.4 | 41.3 | 37.5 | 37.5 | 37.5 per cent |
| Canadian graphite | .. | 5.5 | 9.6 | 13.7 | 12.5 | 12.5 | 12.5 per cent |
| Dorset ball clay | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 37.5 | 40.0 per cent |
| Pot shell | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 per cent |
| Georgia kaolin | .. | .. | .. | .. | 5.0 | 2.5 | .. per cent |
| [1]Per cent Ceylon graphite | 100 | 90 | 82½ | 75 | 75 | 75 | 75 per cent |
| Per cent Canadian graphite | 0 | 10 | 17½ | 25 | 25 | 25 | 25 per cent |

Ten crucibles of No. 70 size were made from each body and shipped to foundry No. 1 for tests. The crucibles were over a week in transit arriving at the foundry November 17th. They were immediately placed in the drier which is heated by steam coils and operated at a temperature of 100° to 110° C.

On December 2nd, two representatives of the Ceramic Station arrived at the foundry to conduct the tests. The crucibles therefore had received 15 days' drying when the tests were started.

The foundry was making several different alloys. Of these, two were produced in greatest quantities. These were called brass No. 3 and brass M1 and were selected as the brasses on which the crucibles were tested. Their compositions are given in Table 2.

TABLE 2.—BRASS COMPOSITIONS.

| | No. 3. Per cent. | M1. Per cent. |
|---|---|---|
| Copper | 78.00 | 71.00–73.00 |
| Zinc | 12.00 | 19.25–21.25 |
| Lead | 7.00 | 5.50– 6.50 |
| Tin | 3.00 | 1.50– 2.50 |

[1] Per cent graphite is reported on a basis of 100 parts graphite in the mix. The graphite was screened between 14 and 100 mesh.

The No. 3 brass requires a higher temperature for melting and a longer period of heating. "Rilton's Brass Cleaner" is introduced with the charge of "M1" and carbonate of soda with No. 3. The composition of Rilton's brass cleaner is not given. Its corrosive action on the crucible was less severe than the carbonate of soda, which attacked the crucibles vigorously and seemed to dissolve the clay bond and loosen the graphite grains.

Crucibles not failing through cracking, pinholing, breaking or scalping, gradually wasted away from the insides until the walls became so thin that it would be dangerous to use them again. Such crucibles generally tested high and were classed by the foundry superintendent as "freaks."

The data on the tests for the ten crucibles of each composition are given in Tables 3 to 9 and the average results are compared in Table 10.

The results of the tests are comparatively consistent on crucibles of No. 50 composition as shown in Table 3. This is especially noticeable in the tests on No. 3 brass which show an improve-

TABLE 3.—TESTS ON NO. 50 COMPOSITION—CRUCIBLE SIZE NO. 70.

| Wt. lbs., crucible. | No. of furnace. | Average minutes per heat. | No. days in drier. | Kind of brass. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|
| 33 | 25 | 103 | 15 | No. 3 | 11 | Pinholing |
| 33 | 3 | 100 | 17 | No. 3 | 11 | Pinholing |
| 34 | 22 | 119 | 19 | No. 3 | 11 | Cracked around crucible |
| 36 | 23 | 104 | 22 | No. 3 | 12 | Large hole below bulge |
| 35 | 7 | 97 | 22 | No. 3 | 16 | Cracked around crucible |
| 34 | 25 | 123 | 29 | No. 3 | 18 | Pinholing |
| 34 | 31 | 87 | 24 | M1 | 34 | Pinholing |
| 33 | 26 | 133 | 25 | M1 | 36 | Vertical crack at rim |
| 34 | 28 | 93 | 26 | M1 | 30 | Vertical crack at rim |
| 32 | 9 | 83 | 30 | M1 | 35 | Vertical crack at rim |

| Averages. | Wt. crucible, lbs. | Minutes per heat. | No. days in drier. | No. of heats. |
|---|---|---|---|---|
| On No. 3 brass (6 crucibles) | 34.2 | 107.7 | 20.67 | 13.17 |
| On M1 brass (4 crucibles) | 33.2 | 99.0 | 26.25 | 33.75 |
| On No. 3 and M1 | 33.7 | 103.3 | 23.46 | 23.46 |

TABLE 4.—TESTS ON NO. 51 COMPOSITION—CRUCIBLE SIZE NO. 70.

| Wt. lbs., crucible. | No. of furnace. | Average minutes, per heat. | No. days in drier. | Kind of brass. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|
| 32.5 | 19 | 118 | 15 | No. 3 | 8 | Cracked around crucible |
| 34.0 | 23 | 106 | 15 | No. 3 | 9 | Cracked around crucible |
| 33.0 | 25 | 118 | 18 | No. 3 | 13 | Cracked around crucible |
| 33.0 | 4 | 80 | 19 | No. 3 | 9 | Cracked around crucible |
| 32.0 | 13 | 90 | 16 | M1 | 26 | Pinholing |
| 32.5 | 27 | 147 | 16 | M1 | 31 | Vertical cracks at rim |
| 34.0 | 9 | 96 | 16 | M1 | 32 | Bottom broken out |
| 32.0 | 12 | 97 | 16 | M1 | 35 | Pinholing |
| 33.0 | 29 | 92 | 16 | M1 | 36 | Worn too thin |
| 32.5 | 26 | 128 | 16 | M1 | 39 | Worn too thin |

| Averages. | Wt. crucible, lbs. | Min. per heat. | No. days in drier. | No. of heats. |
|---|---|---|---|---|
| On No. 3 brass (4 crucibles) | 33.1 | 105.5 | 16.75 | 9.75 |
| On M1 brass (6 crucibles) | 32.7 | 108.3 | 16.00 | 33.17 |
| On No. 3 and M1 | 32.9 | 106.9 | 16.37 | 21.46 |

TABLE 5.—TESTS ON NO. 52 COMPOSITION—CRUCIBLE SIZE NO. 70.

| Wt. lbs., crucible. | No. of furnace. | Average minutes, per heat. | No. days in drier. | Kind of brass. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|
| 37.0 | 7 | 76 | 15 | No. 3 | 1[1] | Scalping |
| 39.0 | 22 | 109 | 15 | No. 3 | 15 | Hole below bulge |
| 37.5 | 5 | 90 | 17 | No. 3 | 9 | Pinholing |
| 37.0 | 3 | 99 | 18 | No. 3 | 9 | Vertical cracks |
| 35.0 | 2 | 101 | 19 | No. 3 | 3 | Vertical cracks at rim |
| 38.0 | 24 | 126 | 22 | No. 3 | 16 | Vertical cracks |
| 38.0 | 24 | 137 | 29 | No. 3 | 15 | Horizontal crack below bulge |
| 38.0 | 11 | 102 | 19 | M1 | 25 | Vertical cracks |
| 39.0 | 12 | 96 | 23 | M1 | 35 | Bottom broken out |
| 38.0 | 30 | 106 | 27 | M1 | 1[1] | Scalping at bottom |

| Averages. | Wt. crucible, lbs. | Min. per heat. | No. days in drier. | No. of heats. |
|---|---|---|---|---|
| On Brass No. 3 (6 crucibles) | 37.4 | 110.3 | 20.0 | 11.17 |
| On brass M1 (2 crucibles) | 38.5 | 99.0 | 21.0 | 30.0 |
| On No. 3 and M1 | 37.9 | 104.6 | 20.5 | 20.58 |

[1] Rejected, too rapid heating.

TABLE 6.—TESTS ON NO. 53 COMPOSITION—CRUCIBLE SIZE NO. 70.

| Wt. crucible, lbs. | No. of furnace. | Average minutes per heat. | No. days in drier. | Kind of brass. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|
| 40.0 | 24 | 147 | 18 | No. 3 | 1[1] | Scalping (laminated) |
| 37.0 | 15 | 103 | 19 | No. 3 | 9 | Hole at bulge |
| 36.0 | 2 | 85 | 20 | No. 3 | 9 | Pinholing |
| 36.0 | 3 | 93 | 22 | No. 3 | 7 | Broke around crucible |
| 37.0 | 3 | 87 | 23 | No. 3 | 9 | Worn too thin |
| 36.0 | 23 | 121 | 29 | No. 3 | 8 | Pinholing |
| 38.0 | 4 | 92 | 30 | No. 3 | 11 | Vertical crack below bulge |
| 35.0 | 10 | 90 | 16 | M1 | 14 | Pinholing |
| 39.0 | 11 | 95 | 16 | M1 | 22 | Vertical cracks |
| 36.0 | 10 | 113 | 29 | M1 | 2[1] | Shattered (flawed) |

| Averages. | Wt. crucible, lbs. | Min. per heat. | No. days in drier. | No. of heats. |
|---|---|---|---|---|
| On brass No. 3 (6 crucibles) | 36.7 | 97.3 | 23.83 | 8.83 |
| On brass M1 (2 crucibles) | 37.0 | 92.5 | 16.00 | 18.00 |
| On No. 3 and M1 | 36.8 | 94.9 | 19.91 | 13.41 |

TABLE 7.—TESTS ON NO. 54 COMPOSITION—CRUCIBLE SIZE NO. 70.

| Wt. crucible, lbs. | No. of furnace. | Average minutes per heat. | No. days in drier. | Kind of brass. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|
| 34.0 | 23 | 120 | 17 | No. 3 | 5 | Vertical crack, pinholed |
| 34.0 | 5 | 103 | 18 | No. 3 | 4 | Vertical crack at rim |
| 35.0 | 6 | 107 | 18 | No. 3 | 5 | Pinholing |
| 35.0 | 4 | 99 | 22 | No. 3 | 8 | Cracked around crucible |
| 35.0 | 8 | 86 | 23 | No. 3 | 3 | Vertical cracks |
| 36.0 | 4 | 97 | 29 | No. 3 | 8 | Horizontal cracks at bulge |
| 35.0 | 3 | 92 | 30 | No. 3 | 7 | Vertical cracks below bulge |
| 33.5 | 15 | 93 | 16 | M1 | 22 | Vertical cracks at rim |
| 34.5 | 28 | 90 | 16 | M1 | 24 | Cracked around bulge |
| 35.0 | 6 | 86 | 19 | M1 | 8 | Vertical cracks |

| Averages. | Wt. crucible, lbs. | Min. per heat. | No. days in drier. | No. of heats. |
|---|---|---|---|---|
| On brass No. 3 (7 crucibles) | 34.9 | 100.6 | 22.73 | 5.71 |
| On brass M1 (3 crucibles) | 34.3 | 89.7 | 17.0 | 18.00 |
| On brass No. 3 and M1 | 34.6 | 95.1 | 19.86 | 11.85 |

[1] Rejected.

TABLE 8.—TESTS ON NO. 55 COMPOSITION—CRUCIBLE SIZE NO. 70.

| Wt. crucible, lbs. | No. of furnace. | Average minutes per heat. | No. of days in drier. | Kind of brass. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|
| 34.5 | 2 | 101.0 | 15 | No. 3 | 5 | Pinholing |
| 35.0 | 15 | 120.5 | 16 | No. 3 | 9 | Pinholing |
| 35.0 | 2 | 89.0 | 16 | No. 3 | 10 | Cracked around crucible |
| 34.0 | 2 | 93.0 | 17 | No. 3 | 10 | Cracked around crucible |
| 35.0 | 5 | 91.0 | 19 | No. 3 | 13 | Pinholing |
| 34.0 | 3 | 91.5 | 29 | No. 3 | 8 | Vertical crack below bulge |
| 34.0 | 5 | 116.5 | 30 | No. 3 | 5 | Vertical cracks |
| 35.0 | 10 | 93.0 | 18 | M1 | 13 | Pinholing |
| 35.0. | 28 | 86.0 | 24 | M1 | 15 | Pinholing |
| 36.0 | 29 | 90.8 | 26 | M1 | 27 | Vertical crack near rim |

| Averages. | Wt. crucible, lbs. | Min. per heat. | No. days in drier. | No. of heats. |
|---|---|---|---|---|
| On brass No. 3 (7 crucibles) | 34.5 | 97.8 | 20.28 | 8.57 |
| On Brass M1 (3 crucibles) | 35.3 | 89.7 | 22.67 | 18.33 |
| On No. 3 and M1 | 34.9 | 93.7 | 21.47 | 13.45 |

TABLE 9.—TESTS ON NO. 56 COMPOSITION—CRUCIBLE SIZE NO. 70.

| Wt. crucible, lbs. | No. of furnace. | Average minutes per heat. | No. of days in drier. | Kind of brass. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|
| 35.0 | 3 | 92.0 | 15 | No. 3 | 7 | Pinholing |
| 34.0 | 18 | 100.0 | 15 | No. 3 | 12 | Pinholing |
| 35.0 | 3 | 100.5 | 16 | No. 3 | 3 | Vertical cracks |
| 35.0 | 6 | 90.0 | 17 | No. 3 | 5 | Vertical cracks |
| 35.0 | 23 | 108.0 | 18 | No. 3 | 8 | Pinholing |
| 34.0 | 6 | 106.3 | 22 | No. 3 | 11 | Pinholing |
| 35.0 | 2 | 95.0 | 29 | No. 3 | 8 | Vertical crack below bulge |
| 33.5 | 30 | 79.3 | 16 | M1 | 23 | Pinholing |
| 34.0 | 31 | 89.6 | 16 | M1 | 25 | Hole below bulge |
| 35.0 | 14 | 85.0 | 17 | M1 | 28 | Bottom broke on drawing |

| Averages. | Wt. crucible, lbs. | Min. per heat. | No. days in drier. | No. of heats. |
|---|---|---|---|---|
| On brass No. 3 (7 crucibles) | 34.7 | 98.8 | 18.86 | 7.71 |
| On brass M1 (3 crucibles) | 34.2 | 84.6 | 16.33 | 25.33 |
| On No. 3 and M1 | 34.4 | 91.7 | 17.60 | 16.52 |

TABLE 10.—SUMMARY OF TESTS ON SERIES 1.

| Mark. | Average minutes per heat. | | | Average days in drier. | | | Average number of heats. | | |
|---|---|---|---|---|---|---|---|---|---|
| | On No. 3 brass. | On M1 brass. | Av. on No. 3 and M1. | On No. 3 brass. | On M1 brass. | Av. on No. 3 and M1. | On No. 3 brass. | On M1 brass. | Av. on No. 3 and M1. |
| 50 | 107.7 | 99.0 | 103.3 | 20.67 | 26.25 | 23.46 | 13.17 | 33.75 | 23.46 |
| 51 | 105.5 | 108.3 | 106.9 | 16.75 | 16.00 | 16.37 | 9.75 | 33.17 | 21.46 |
| 52 | 110.3 | 99.0 | 104.6 | 20.00 | 21.00 | 20.50 | 11.17 | 30.00 | 20.58 |
| 53 | 97.3 | 92.5 | 94.9 | 23.83 | 16.00 | 19.91 | 8.83 | 18.00 | 13.41 |
| 54 | 100.6 | 89.7 | 95.1 | 22.73 | 17.00 | 19.86 | 5.71 | 18.00 | 11.85 |
| 55 | 97.8 | 89.7 | 93.7 | 20.28 | 22.67 | 21.47 | 8.57 | 18.33 | 13.45 |
| 56 | 98.8 | 84.6 | 91.7 | 18.86 | 16.33 | 17.60 | 7.71 | 25.33 | 16.52 |

ment in the life of the crucible with increase in the length of time of drying. In general this characteristic is shown in the other tests but is not borne out as consistently. Neither the weight of the crucible nor the length of time of heating seem to bear any relation to the crucible's life. However, the rate of heating is important since too rapid heating may cause cracking or scalping. According to Gillett[1] "Allowing the crucible to remain in the fire longer than is necessary; that is, not taking the pot out when the metal is ready, or allowing the metal to 'soak,' increases the wear on the crucible."

In order to compare the serviceability of the crucibles the life of the crucible is expressed in per cent (Table 11) on a basis of 100 for the crucible giving highest service on each brass and on the average for both brasses.

TABLE 11.—PER CENT LIFE OF CRUCIBLES.

| Mark. | On No. 3 brass. | On M1 brass. | Av. on No. 3 and M1. |
|---|---|---|---|
| 50 | 100.00 | 100.00 | 100.00 |
| 51 | 74.03 | 98.28 | 91.47 |
| 52 | 84.05 | 88.89 | 87.72 |
| 53 | 67.05 | 53.33 | 57.16 |
| 54 | 43.36 | 53.33 | 50.51 |
| 55 | 65.07 | 54.31 | 57.33 |
| 56 | 58.54 | 75.05 | 70.42 |

[1] Loc. cit., 165.

The replacement of Ceylon graphite by the Canadian graphite has decreased the life of the crucible up to a replacement of 25 per cent, which has evidently lowered the service of the crucible by nearly 33 per cent on brass No. 3, $46^2/_3$ per cent on brass M1, and nearly 43 per cent on the average for both brasses.

In Nos. 54, 55 and 56, the ratio of Ceylon to Canadian graphite remains constant at 75 per cent to 25 per cent. As compared to No. 53, five parts of the graphite are replaced by clay. In No. 54 the replacement is Georgia kaolin and has evidently resulted in lowering the life of the crucible.

Georgia kaolin is very refractory and is a clay of low bonding strength as compared to bonds of the ball clay type. At brass melting temperatures, Georgia kaolin remains too porous and friable to impart strength and resistance to slagging action. However, at steel melting temperatures, the use of a small amount of Georgia kaolin in the crucible would in all probability be beneficial.

In No. 55 as compared to No. 54, $2^1/_2$ parts Georgia kaolin is replaced by Dorset ball clay. The replacement has improved the life of the crucible and has resulted in a crucible giving equally as good service as No. 53. Evidently the good effects of the ball clay have balanced the ill effects of the kaolin.

A comparison of No. 56 with No. 53 shows an improvement in the life of the crucible by the replacement of 5 parts of graphite by 5 parts Dorset ball clay as against a decrease in service by an equal substitution of kaolin for graphite (No. 54).

The Ceylon graphite has a granular or splintery form with a comparatively low surface factor and low bulkiness, while the Canadian grain is thin, plate-like in form, of high surface factor and higher bulkiness. Therefore, more clay is necessary to bond the flake graphite than is necessary for bonding the Ceylon graphite. The average results indicate an improvement in the life of the crucible by an increase of 5 parts ball clay at the expense of graphite.

### Series 2.

Series 2 consisted of two members, Nos. 58 and 59. Fifteen crucibles of each of No. 80 D-size were tested. The graphite

in No. 58 was Canadian flake and that in No. 59 a mixture of 75 per cent Ceylon and 25 per cent Canadian flake. Compositions of the crucibles are given in Table 12.

TABLE 12.

| Mark. | No. 58. | No. 59. |
|---|---|---|
| Ceylon graphite | 0.0 per cent | 41.25 per cent |
| Canadian graphite | 55.00 per cent | 13.75 per cent |
| Dorset ball clay | 35.00 per cent | 35.00 per cent |
| Pot shell | 5.00 per cent | 5.00 per cent |
| Sand | 5.00 per cent | 5.00 per cent |

The crucibles were tested at foundry No. 2. The drier at this foundry is operated at a temperature varying from 90° to 110° C. The heat is supplied by hot air from a "stove" outside of the drying room. After the crucibles had received $3^1/_2$ days' drying treatment, the tests were made. It was realized that the short

TABLE 13.—TESTS OF NO. 58 COMPOSITION—CRUCIBLE SIZE NO. 80 D.

| No. of furnace. | Days in drier. | Av. minutes per heat. | No. of heats. | Cause of failure. |
|---|---|---|---|---|
| 3 | 3.5 | 55 | 13 | Bottom cracked, careless handling |
| 4 | 3.5 | 55 | 13 | Bottom cracked, careless handling |
| 1 | 4.5 | 55 | 13 | Large hole in side |
| 2 | 4.5 | 55 | 13 | Horizontal crack at middle |
| 3 | 5.5 | 55 | 7 | Broken in half on removal, 8th heat |
| 4 | 5.5 | 55 | 13 | Pinholing |
| 6 | 5.5 | 55 | 15 | Vertical crack at rim |
| 8 | 5.5 | 55 | 19 | Horizontal crack at middle |
| 1 | 5.5 | 55 | 12 | Broke on removal from furnace |
| 2 | 5.5 | 55 | 12 | Bottom broke on charging |
| 4 | 5.5 | 55 | 11 | Large hole in side |
| 5 | 5.5 | 55 | 12 | Pinholing |
| 6 | 5.5 | 55 | 6 | Vertical crack at rim |
| 7 | 5.5 | 55 | 11 | Pinholing |
| 1 | 8.5 | 55 | 12 | Pinholing |

Total heats, 15 crucibles..... 182.
Average heats per crucible..... 12.13
Graphite—100 per cent Canadian.

drying period was insufficient and would be detrimental to the life of the crucibles, but owing to lack of time, it was considered that comparable results would be obtained from the tests on 15 crucibles of each composition.

The tests were made on brass composed of 70 per cent copper and 30 per cent zinc. About half the charge was scrap and half new metal. After the charge had melted and about 15 minutes before removing the crucibles for pouring, a hand-full of salt and a shovel-full of charcoal were thrown on top of the metal. The results of the tests are given in Tables 13 and 14.

TABLE 14.—TESTS OF NO. 59 COMPOSITION—CRUCIBLE SIZE NO. 80 D.

| No. of furnace. | Days in drier. | Av. minutes per heat. | No. of heats. | Cause of failure. |
|---|---|---|---|---|
| 1 | 3.5 | 55 | 13 | Pinholing |
| 2 | 3.5 | 55 | 20 | Top worn down |
| 3 | 4.5 | 55 | 13 | Pinholing |
| 4 | 4.5 | 55 | 13 | Pinholing |
| 1 | 5.5 | 55 | 18 | Vertical crack at middle |
| 2 | 5.5 | 55 | 11 | Vertical crack at middle |
| 5 | 5.5 | 55 | 12 | Vertical crack at middle |
| 7 | 5.5 | 55 | 15 | Vertical crack below bulge |
| 3 | 5.5 | 55 | 22 | Pinholing |
| 4 | 5.5 | 55 | 5 | Broken by tongs in placing |
| 7 | 5.5 | 55 | 16 | Pinholing |
| 1 | 5.5 | 55 | 4 | Horizontal crack, squeezed by tongs |
| 2 | 5.5 | 55 | 7 | Horizontal crack, squeezed by tongs |
| 3 | 5.5 | 55 | 9 | Horizontal crack at middle |
| 3 | 8.5 | 55 | 11 | Broken around bulge |

Total number of heats, 15 crucibles..... 189.00
Average number of heats per crucible..... 12.60
Graphite, 75 per cent Ceylon and 25 per cent Canadian.

The difference in the lives of the Nos. 58 and 59 crucibles was small, having been less than $^1/_2$ heat per crucible. The comparison of service on a percentage basis is; No. 58, 96.27 per cent; and No. 59, 100 per cent.

### Series A and B.

Series A was made in order to observe the effect of replacing Ceylon graphite by Alabama No. 1 crucible flake graphite. In

series B, "coked" Alabama graphite replaced the Ceylon. In order to change the flake form of graphite to the granular form, a mixture of three parts Alabama flake graphite, between 20 and 100 mesh size, and 1 part dust passing the 100 mesh sieve was briquetted with 15 per cent tar under a pressure of 5000 pounds per square inch, coked at 1000° C, crushed, screened through 16 mesh and passed over a 100 mesh screen to remove the surplus fines.

The Ceylon graphite was graded so as to produce the same screen analysis as the coked Alabama. The Alabama crucible flake, which all passed through the 20 mesh screen, was used as received from the dealer. The screen analyses are given in Table 15 and the compositions of series A and B in Tables 16 and 17.

Four crucibles of each member of the A and B series were made in No. 60 size and were originally intended for tests in a brass foundry at Columbus, Ohio, but owing to the fact that the output of the foundry was small, and that no adequate drier was

TABLE 15.

| | Coked Alabama. | Ceylon. | Alabama flake. |
|---|---|---|---|
| Between 16 and 20 mesh | 16.0 | 16.0 | 0.0 |
| Between 20 and 40 mesh | 25.0 | 25.0 | 11.0 |
| Between 40 and 100 mesh | 55.0 | 55.0 | 85.5 |
| Through 100 mesh | 4.0 | 4.0 | 3.5 |

TABLE 16.—COMPOSITIONS, SERIES A.

| Mark. | A—1. | A—2. | A—3. | A—4. | A—5. |
|---|---|---|---|---|---|
| Ceylon graphite | 55.0 | 42.5 | 30.0 | 17.5 | 0.0 |
| Alabama graphite | 0.0 | 12.5 | 25.0 | 37.5 | 53.0 |
| Dorset ball clay | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| McLendon bond clay | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Kentucky ball clay | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Illinois kaolin | 5.0 | 5.0 | 5.0 | 5.0 | 7.0 |
| Glass sand | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Per cent Alabama graphite | 0 | 22.73 | 45.45 | 68.18 | 100 |
| Per cent Ceylon graphite | 100 | 77.27 | 54.55 | 31.82 | 0 |

TABLE 17.—COMPOSITIONS, SERIES B.

| Mark. | B—1. | B—2. | B—3. | B—4. |
|---|---|---|---|---|
| Ceylon graphite | 42.5 | 30.0 | 17.5 | 0.0 |
| Coked Alabama graphite | 12.5 | 25.0 | 37.5 | 53.0 |
| Dorset ball clay | 20.0 | 20.0 | 20.0 | 20.0 |
| McLendon bond clay | 10.0 | 10.0 | 10.0 | 10.0 |
| Kentucky ball clay | 5.0 | 5.0 | 5.0 | 5.00 |
| Illinois kaolin | 5.0 | 5.0 | 5.0 | 7.0 |
| Glass sand | 5.0 | 5.0 | 5.0 | 5.0 |
| Per cent coked Alabama graphite | 22.73 | 45.45 | 68.18 | 100 |
| Per cent Ceylon graphite | 77.27 | 54.55 | 31.82 | 0 |

TABLE 18.—SERIES A, CRUCIBLE SIZE NO. 60.

| Mark. | Wt. crucible, lbs. | Days in drier. | No. of furnace. | Kind of brass. | Average minutes per heat. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|---|
| A1 | 30.0 | 19 | 2 | No. 3 | 92.50 | 5 | Vertical cracks below bulge |
| A1 | 31.0 | 23 | 4 | No. 3 | 91.00 | 9 | Vertical cracks below bulge |
| A1 | 31.0 | 20 | 10 | M1 | 94.00 | 10 | Pinholing |
| A1 | 30.0 | 22 | 31 | M1 | 124.00 | 7 | Pinholing |
| A2 | 31.0 | 17 | 8 | No. 3 | 86.80 | 7 | Vertical cracks |
| A2 | 30.5 | 18 | 22 | No. 3 | 110.00 | 9 | Horizontal crack at bulge |
| A2 | 28.0 | 23 | 29 | M1 | 92.67 | 15 | Pinholing |
| A2 | 30.0 | 26 | 10 | M1 | 74.00 | 8 | Pinholing |
| A3 | 30.0 | 15 | 4 | No. 3 | 89.00 | 10 | Vertical cracks at bulge |
| A3 | 30.0 | 17 | 15 | No. 3 | 99.00 | 13 | Vertical cracks |
| A3 | 30.0 | 19 | 5 | M1 | 86.43 | 27 | Pinholing at bottom |
| A3 | 29.0 | 29 | 30 | M1 | 86.33 | 21 | Worn too thin |
| A4 | 30.0 | 18 | 4 | No. 3 | 94.00 | 8 | Cracked diagonally at bulge |
| A4 | 29.0 | 19 | 23 | No. 3 | 112.00 | 9 | Horizontal crack at bottom |
| A4 | 28.0 | 19 | 28 | M1 | 109.40 | 20 | Pinholing |
| A4 | 29.0 | 20 | 13 | M1 | 96.00 | 20 | Vertical cracks |
| A5 | 28.0 | 22 | 15 | No. 3 | 103.00 | 12 | Pinholing |
| A5 | 27.0 | 22 | 25 | No. 3 | 120.00 | 15 | Cracked around crucible |
| A5 | 28.0 | 25 | 11 | M1 | 96.33 | 29 | Vertical crack near bottom |
| A5 | 26.0 | 29 | 10 | M1 | 84.60 | 28 | Vertical crack at bulge |

available, a more suitable place was sought for the testing. A communication with the superintendent of foundry No. 1 brought

forth the reply that he could use the crucibles, although their equipment was designed to handle No. 70 size.

The A and B series were shipped to foundry No. 1 with the crucibles of Series 1 and tested at the same time. The A and B series were placed in the drier at the same time as Series 1 and therefore received 15 days' drying before the tests were begun.

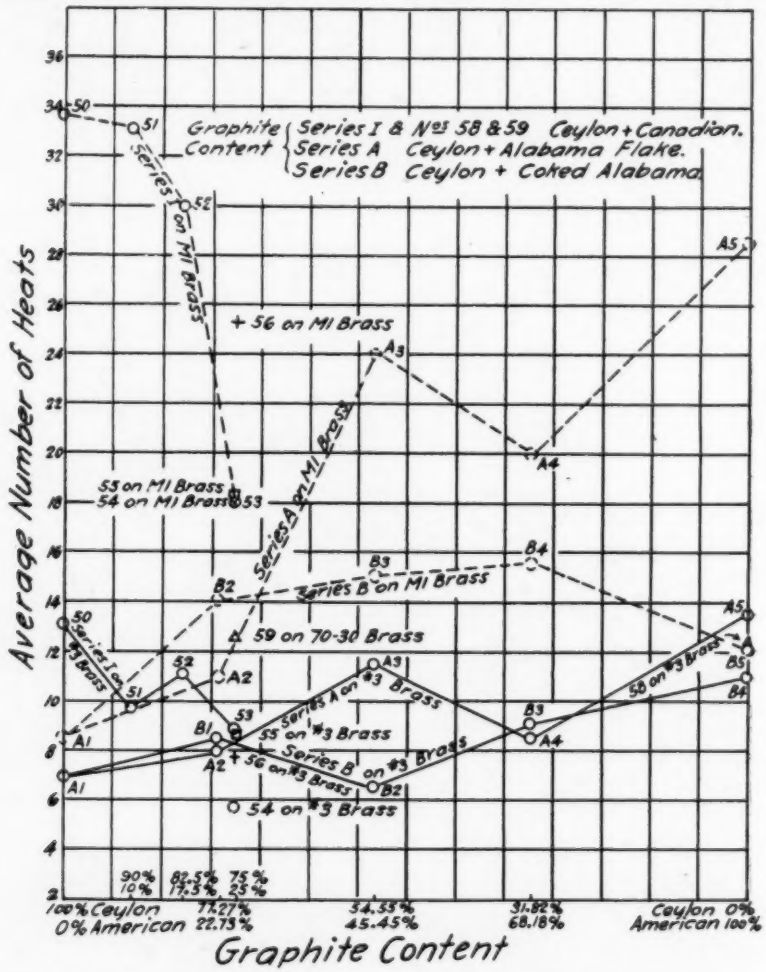

Average Number of Heats
Graphite Content
Graphite Content { Series I & Nos 58 & 59 Ceylon + Canadian.
Series A Ceylon + Alabama Flake.
Series B Ceylon + Coked Alabama.
Series I on MI Brass
+ 56 on MI Brass
53 on MI Brass
54 on MI Brass
Series A on MI Brass
Series B on MI Brass
59 on 70-30 Brass
Series I on #3 Brass
Series A on #3 Brass
55 on #3 Brass
Series B on #3 Brass
+ 56 on #3 Brass
54 on #3 Brass
58 on #3 Brass
90% 10%
82.5% 17.5%
75% 25%
100% Ceylon 0% American
77.27% 22.73%
54.55% 45.45%
31.82% 68.18%
Ceylon 0% American 100%

FIG. 1.—Average number of heats on different brasses.

During the tests it was observed, by the two representatives conducting the tests, that the equipment of the foundry was not suited to the No. 60 size crucibles. This was especially noticeable in the lifting tongs which were designed to fit the No. 70 size, and the lives of the smaller crucibles were affected by the unequal squeezing of the tongs. Since the tongs were of the grab type, the pressure on the crucible depended upon the weight of the crucible and its charge, so that the squeezing effect was more or less constant for all crucibles of the same size.

The crucibles were tested on both No. 3 and M1 brass. Tests for Series A are recorded in Table 18, Series B in Table 19, and the average tests for both series in Table 20.

The number of crucibles tested in series A and B is not sufficient from which conclusions can be accurately drawn. Owing to the erratic behavior of crucibles in use, at least ten crucibles of each composition should be tested. At the time the crucibles

TABLE 19.—SERIES B, CRUCIBLE SIZE NO. 60.

| Mark. | Wt. crucible, lbs. | Days in drier. | No. of furnace. | Kind of brass. | Average minutes per heat. | No. of heats. | Cause of failure. |
|---|---|---|---|---|---|---|---|
| B1 | 32.0 | 20 | 3 | No. 3 | 90.00 | 5 | Vertical cracks |
| B1 | 31.0 | 23 | 22 | No. 3 | 107.00 | 12 | Vertical and horizontal cracks |
| B1 | 31.5 | 24 | 30 | M1 | 89.00 | 15 | Pinholing |
| B1 | 31.0 | 29 | 13 | M1 | 95.33 | 13 | Pinholing |
| B2 | 29.0 | 17 | 4 | No. 3 | 102.50 | 5 | Vertical cracks at bulge |
| B2 | 30.0 | 23 | 8 | No. 3 | 108.33 | 8 | Vertical cracks |
| B2 | 29.0 | 24 | 23 | M1 | 107.33 | 9 | Vertical cracks |
| B2 | 30.0 | 24 | 27 | M1 | 132.50 | 21 | Vertical cracks at rim |
| B3 | 31.0 | 20 | 4 | No. 3 | 85.0 | 1[1] | Cracked, too rapid heating |
| B3 | 29.0 | 22 | 5 | No. 3 | 100.00 | 9 | Vertical cracks |
| B3 | 31.0 | 26 | 14 | M1 | 124.67 | 15 | Vertical cracks below bulge |
| B3 | 31.0 | 30 | 27 | M1 | 122.50 | 16 | Pinholing |
| B4 | 28.0 | 18 | 24 | No. 3 | 134.75 | 14 | Cracked around crucible |
| B4 | 30.0 | 23 | 2 | No. 3 | 99.00 | 8 | Vertical cracks |
| B4 | 29.0 | 20 | 30 | M1 | 113.67 | 10 | Pinholing |
| B4 | 29.0 | 30 | 14 | M1 | 91.67 | 14 | Vertical crack at bulge |

[1] Rejected.

TABLE 20.—AVERAGE TESTS ON SERIES A AND B.

| Mark. | Average minutes per heat. | | | Average days in drier. | | | Average number of heats. | | |
|---|---|---|---|---|---|---|---|---|---|
| | On brass No. 3. | On brass M1. | Av. on No. 3 and M1. | On brass No. 3. | On brass M1. | Av. on No. 3 and M1. | On brass No. 3. | On brass M1. | Av. on No. 3 and M1. |
| A1 | 91.7 | 109.0 | 100.4 | 21.0 | 21.0 | 21.0 | 7.0 | 8.5 | 7.75 |
| A2 | 98.4 | 83.3 | 90.8 | 17.5 | 24.5 | 21.0 | 8.0 | 11.0 | 9.75 |
| A3 | 94.0 | 86.4 | 90.2 | 16.0 | 24.0 | 20.0 | 11.5 | 24.0 | 17.75 |
| A4 | 103.0 | 102.7 | 102.8 | 18.5 | 19.5 | 19.0 | 8.5 | 20.0 | 14.25 |
| A5 | 111.5 | 90.5 | 101.0 | 22.0 | 27.0 | 24.5 | 13.5 | 28.5 | 21.00 |
| B1 | 98.5 | 92.2 | 95.3 | 21.5 | 26.5 | 24.0 | 8.5 | 14.0 | 11.25 |
| B2 | 105.4 | 119.9 | 112.6 | 20.0 | 24.0 | 22.0 | 6.5 | 15.0 | 10.75 |
| B3 | 92.5 | 123.6 | 108.0 | 21.0 | 28.0 | 24.5 | 9.0 | 15.5 | 12.25 |
| B4 | 116.9 | 102.6 | 109.7 | 20.5 | 25.0 | 22.7 | 11.0 | 12.0 | 11.50 |

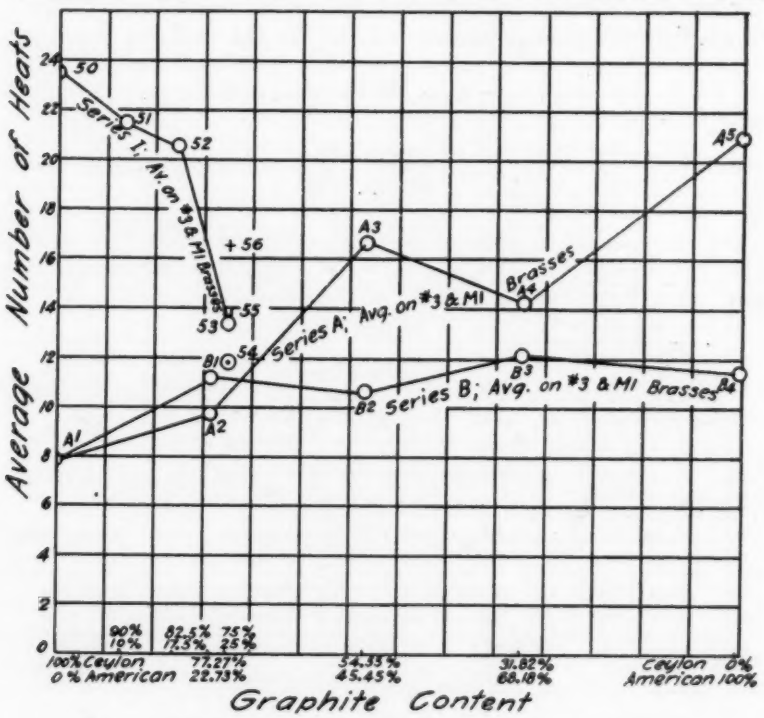



FIG. 2.—Number of heats averaged on Nos. 3 & M1 brasses.

were made, the materials on hand were limited, which limited the number of crucibles to four for each composition.

The average results for the crucibles tested on the different brasses are plotted in Fig. 1 and the average results of the tests on No. 3 and M1 brasses are shown graphically in Fig. 2.

In Fig. 1 the curves showing the behavior of Series A on both brasses show considerable similarity. The curves take the same general direction, rising and falling at the same corresponding points, but this similarity is lacking in the other series.

## Conclusions.

In so far as the work has progressed, it shows that the substitution of Canadian graphite up to 25 per cent for Ceylon, decreased the life of the crucible (Series 1). Crucibles containing 100 per cent Canadian graphite gave nearly as good service as those containing 25 per cent Canadian and 75 per cent Ceylon (Series 2). The substitution of Alabama flake graphite for the Ceylon improved the crucible's life (Series A). The substitution of coked Alabama graphite for the Ceylon improved the life of the crucible (Series B). The substitution of the coked Alabama graphite for the Alabama flake up to 22.73 per cent increased and higher substitutions decreased the life of the crucible (Series A and B, Fig. 2). No material advantage was gained by converting the Alabama flake graphite to the granular form.

In crucibles containing 75 per cent Ceylon and 25 per cent Canadian graphite, the increase in clay content by Georgia kaolin lowered the life of the crucible. Replacement of the kaolin by Dorset ball clay improved the life of the crucible (Nos. 53, 54, 55 and 56, Fig. 2).

The marked difference in the service of A1 and No. 50 is noteworthy. Both contain all Ceylon graphite. A1 was smaller by three pints capacity than No. 50. The smaller the crucible the greater the number of heats it should stand, according to the curves shown by Gillett;[1] in which the service of the crucible, expressed in number of heats, is plotted against the maker's number. A No. 60 size crucible should stand approximately $4^1/_4$ per cent more heats than a No. 70 size. This appears to be

[1] Loc. cit., p. 159.

the only advantage that A1 might have over No. 50. The advantage is small and is more than offset by the disadvantages.

The larger the crucible the larger should be the graphite grains, in order to produce a crucible of maximum strength and service. The graphite in No. 50 was screened between 14 and 100 mesh, whereas, the graphite in A1 was screened through 16 mesh. The graphite of No. 50 showed considerably more material remaining on the 40 mesh screen than the graphite of A1. In respect to size of grain, No. 50 crucibles had the advantage. Not only was A1 at a disadvantage with respect to size of grain, but its life was also materially affected by unequal squeezing of the ill-fitting tongs.[1]

Crucibles giving highest average service on M1 brass and on the averages for both No. 3 and M1, were those containing all Ceylon graphite (No. 50), whereas, the crucible giving highest service on No. 3 brass was A5 in which the graphite was all Alabama flake. It therefore appears that the Alabama graphite offers promising possibilities for the manufacture of graphite crucibles.

When the refining process is completed the No. 1 Alabama flake seldom exceeds 20 mesh in size. Its crucible-making value would therefore be limited by the size of the crucible—it being doubtful whether it could be used successfully for the manufacture of the larger sizes. By the judicious use of sand and pot-shell, to overcome the slipperiness and tendency to laminate, it is probable that crucibles giving high service can be made from Alabama graphite up to a No. 70 size or even larger.

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[1] See Gillett, Loc. cit., pp. 161–163.

# IMPACT TESTS AND POROSITY DETERMINATIONS ON SOME AMERICAN HOTEL CHINA AND SEMI-PORCELAIN PLATES.[1]

By Homer F. Staley and J. S. Hromatko, Washington, D. C.

## Impact Tests.

Determination of the physical properties of chinas and semi-porcelains offer no particular difficulties when test pieces suitable for use in the various kinds of apparatus ordinarily employed in testing laboratories can be made to order. It is then possible to determine with a fair degree of accuracy the cross-bending strength, the crushing strength, modulus of rupture or any other mechanical characteristic desired.

Conditions are altogether different when it comes to making tests for determining the serviceability of manufactured wares such as hotel chinas. In the first place the forms of the pieces available for testing are not suited for use in most testing machines. Moreover, the variety of ways in which a piece may fail in service makes it necessary to determine just what properties are to be studied and to actually correlate the tests conducted with service conditions.

Hotel table wares fail in three ways, by marring of the glaze, by chipping, and by breaking. The marring of the glaze by cutlery marks may be due to chemical instability of the glaze, as pointed out by Ashley,[2] or to abrasion. A combination of chemical tests and some form of light impact or abrasion test would seem to be appropriate for determining the liability of glazes to fail in this manner.

Chipping is the result of blows too light to cause cracking of the ware. For determining resistance to failure in this way an impact test of moderate intensity should be satisfactory. A true impact machine may be used or some form of rattler. The

[1] By permission of the Director, Bureau of Standards.

[2] *Trans. Am. Ceram. Soc.*, **13**, 226 (1911).

latter machines give a combination of impact and rubbing actions. In a variety of forms they have been used by Watts,[1] Ellsworth Ogden,[2] Lester Ogden,[3] and others for determining the resistance to abrasion of porcelain samples. The use of rattler machines for testing plates and similar articles of table ware is attended by difficulties. The pieces are too large to be used whole, and if they are broken up, the presence of raw edges and sharp corners introduces factors not operative in actual service.

Breaking of table wares in service is in the great majority of cases due to severe impact caused by the dropping of the piece. A true impact test seems to be indicated for determining the resistance of wares to failure in this way. The impact necessary to break a piece of ware and the type of apparatus to be used in testing depend, among various things, on the shape and size of the piece. In this work, seven-inch plates, which were actually about nine inches in diameter, were used as samples.

When a plate is dropped it may fall face downward, on edge, or with the foot downward, and the probability of breaking will vary with the manner in which it falls. Experience has proven that they seldom fall face downward, often fall on edge, but most often fall foot downward. This is no doubt due to the shape of the piece and the weight of the foot. When a plate falls foot downward, the probabilities are against it falling perfectly flat on to a perfectly flat surface. When such cases do occur, the force of the impact is distributed through the whole foot, and the method of failure is different from that in the more common case where one part of the foot strikes first and takes the force of the blow.

The manner in which a broken plate fell may often be determined by study of the location of the fractures. Fig. 1 shows the fracture characteristic of a plate broken by being dropped on edge. Fig. 2 shows the breaking in an irregular manner into many small pieces of a plate dropped foot downward squarely onto a smooth, flat surface. When one point of the foot of the plate strikes first, the result is a V-shaped break. In Fig. 3

[1] *Trans. Am. Ceram. Soc.*, **4**, 107 (1901 2).
[2] *Ibid.*, **7**, 370 (1905).
[3] *Ibid.*, **13**, 395 (1911-2).

we see three lines of fracture radiating from the point of the foot on which a plate falling in this manner struck. Of course these typical fractures are not invariably shown. It is very probable

FIG. 1.

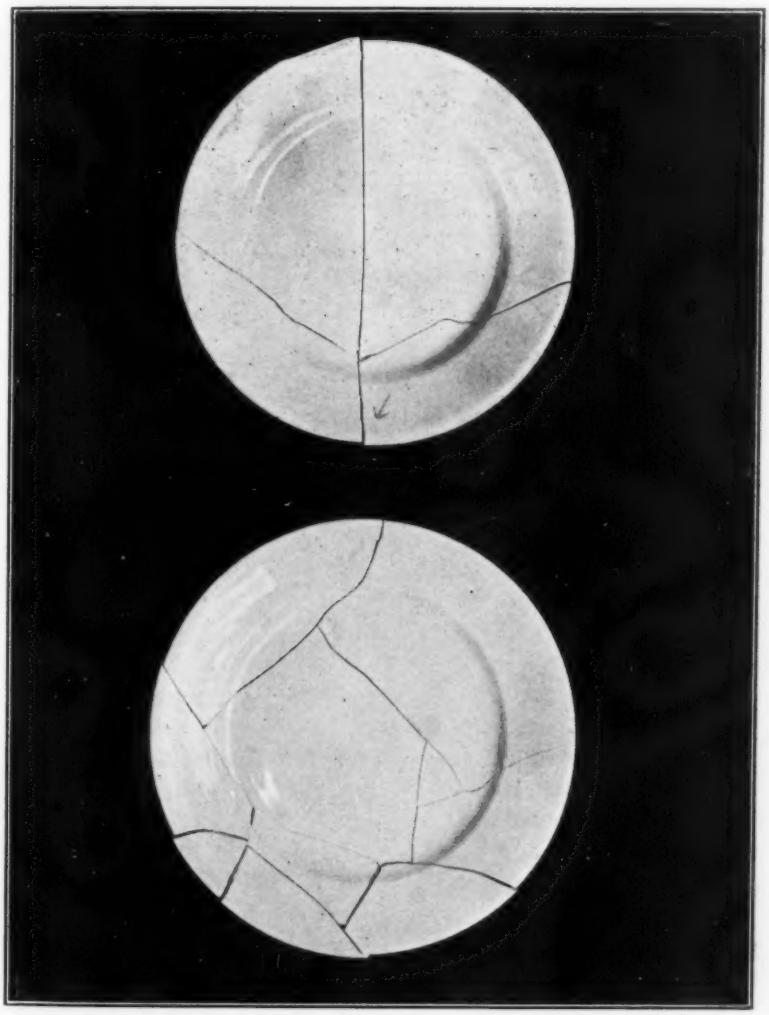

FIG. 2.

that Figs. 1 and 3 show simply variations of the same general type of failure, for sometimes a plate falling on edge may have the kind of fracture shown in Fig. 3 and one falling on one point

FIG. 3.

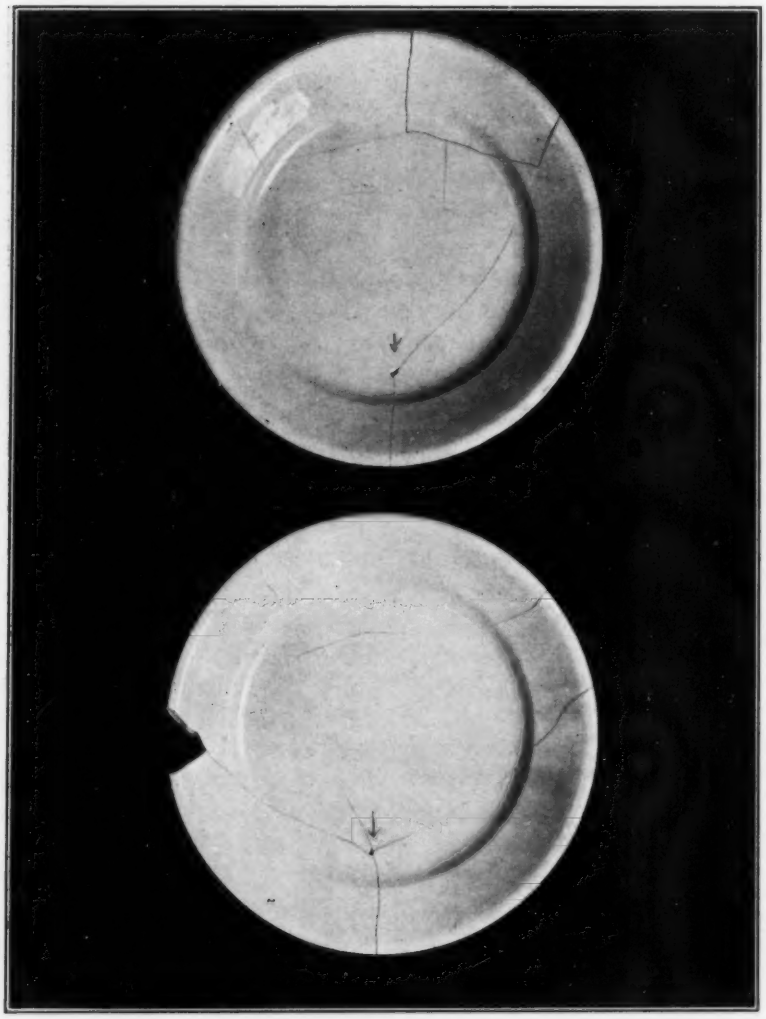

FIG. 4.

of the foot may have the kind of break shown in Fig. 1. This would indicate that failure of the foot at one point is the controlling factor when a plate breaks from falling either onto its edge or

FIG. 5.

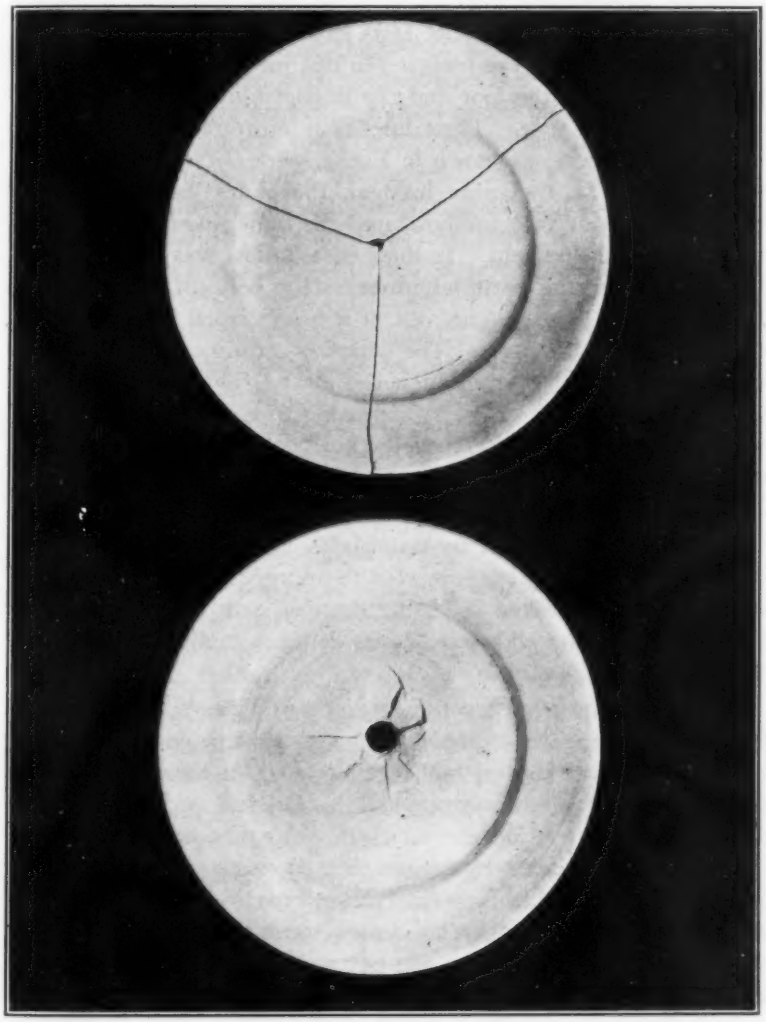

FIG. 6.

one point of its foot. That the impact tests used in this work approximated the conditions obtaining when a plate falls onto one point of its foot is shown by Fig. 4, which is characteristic of the majority of the breaks obtained in these tests.

In the preliminary work incident to these tests two attempts were made to employ impact tests in which the point of impact was at the center of the plates. In one method, the plates were bedded solidly on the foot and the impact blow was delivered in the center of the face. Three lines of fracture radiating from the center of the piece, as shown in Fig. 5, were obtained with every plate tested. In the other method, the plates were bedded on a ring just fitting into the bowl and the blow was delivered onto the center of the bottom. In these cases failure was characterized by crushing of the material immediately beneath the point of impact and by the breaking out of a cone shaped section on the opposite side of the plate. The action was the same as if a blunt punch had been driven through the plate. This type of failure is illustrated in Fig. 6. It is interesting to note that with plates of the same make in the first method of testing the average energy of impact necessary to produce fracture was 0.45 foot-pounds, and in the second was 1.44 foot pounds.

It was finally decided to test plates by impact on one spot on the foot. This test is supposed to approximate the conditions when a plate is broken by being dropped onto one spot on its foot which is, as stated above, a very common manner of breaking in service.

The apparatus used for the impact tests was a heavy metal frame for holding the samples and a pendulum consisting of a $1\frac{1}{4}$ pound flattened steel ball at the end of a 24-inch thin and stiff wire arm. The hammer had a spherical striking surface with a radius of $1\frac{1}{8}$ inches. A clear, white pine board, $\frac{5}{8}$ inch thick, was placed in the frame and then the plate to be tested was held loosely against this. The various parts of the apparatus were so spaced that with this arrangement the point of impact of the hammer would be on the bottom of the foot of the plate and directly below the point of suspension of the pendulum.

Preliminary tests had shown that clamping the plate solidly

against the bearing board introduced pressure strains not present when a plate is dropped and also influenced the distribution of the shock in such manner that both the energy necessary to produce fracture and the type of fracture were altered. In the course of the tests it was found that some makes of vitrified china plates were warped so badly that the use of a bearing plate accommodating itself more readily to irregularities of structure would have been desirable. Such a bearing plate would probably have given more uniform results in some of the individual lots of plates and higher results in all lots. However, it is not probable that it would have altered the relative positions of the various lots. It is rather difficult to determine the effect of highly resilient bearing plates, and the use of these in testing should be avoided when possible.

In making the tests the pendulum was first allowed to swing through 30 degrees, then 35 degrees, and so on, the angle of swing being increased each time by five degrees until fracture occurred.

The energy of impact of a swinging pendulum, neglecting the effect of friction and the weight of the arm, is given by the simple formula

(1) $$E = HW$$

in which

E = energy of impact in foot-pounds.
H = height of drop in feet.
W = weight of hammer in pounds.

The value of H may be determined by direct measurement or by calculation. When the angle of swing is less than 90 degrees and the point of impact is located, as in this case, perpendicularly below the point of suspension, H is given by the formula

(2) $$H = 1 - \text{cosine angle A} \times L$$

in which

Angle A = angle with vertical made by pendulum arm at time of release;
L = length of arm in feet.

Substitution of this value of H in Formula 1 gives

(3) $$E = 1 - \text{cosine angle A} \times L \times W.$$

The results of the tests were calculated by this formula in all cases in which the angle of swing was less than 90 degrees. Of

course when the angle is 90 degrees, H equals L. If the pendulum arm is sufficiently rigid to prevent bending during the dropping of the hammer, the same apparatus may be used, and H can be calculated for angles of swing greater than 90 degrees by the following formula:

$$H = (1 + \text{sine angle A})\, L \qquad (4).$$

This formula was used for the angle of swing of 95 degrees used in one case.

It is impossible to figure the cumulative effect of blows of increasing severity, due to lack of data on the mechanical properties of semi-porcelain and china. The work of O'Connor[1] on impact tests of tiles indicates that the energy of impact necessary to produce fracture in these materials is not materially affected by previous blows not sufficiently severe to produce fracture.

TABLE I.—VALUE OF I — COSINE ANGLE A FOR VARIOUS ANGLES.

| Angle in degrees. | Value of 1 — cosine. | Angle in degrees. | Value of 1 — cosine. | Angle in degrees. | Value of 1 — cosine. |
|---|---|---|---|---|---|
| 5 | 0.00381 | 35 | 0.18085 | 65 | 0.57738 |
| 10 | 0.01519 | 40 | 0.23396 | 70 | 0.65798 |
| 15 | 0.03408 | 45 | 0.29289 | 75 | 0.74118 |
| 20 | 0.06031 | 50 | 0.35721 | 80 | 0.82635 |
| 25 | 0.09369 | 55 | 0.42642 | 85 | 0.91285 |
| 30 | 0.13397 | 60 | 0.50000 | 90 | 1.00000 |

The data of the impact tests are shown in Tables 2 and 3. Examination of these shows that the total variation in value of energy of impact in individual groups was quite large. As stated above this may be due in part to the poor bedding of warped plates, which would tend to give low values. However, the values for the different lots of plates fall into distinct groups. The relative rating of the different groups according to average energy of impact is not altered if we select as the basis of rating either the maximum individual value in each group or the average of either the three of four highest values in each group. It is not materially changed if we rate the groups according to the minimum value in each group. Of course, it is realized that a larger number of samples would have been desirable, but these were not available. Since this work was rather a pioneer attempt in the field, and gives results of considerable significance, it is to be expected that it will lead to more comprehensive investigations

[1] *Trans. Am. Ceram. Soc.*, **15**, 232 (1913).

These tests show rather conclusively that the seven lots of heavy hotel-ware plates tested varied distinctly in their ability to withstand impact blows similar to those such wares are subjected to in service. Also, that as far as withstanding heavy impact is concerned the china plates were not superior to the semi-porcelains. It should be noted, however, that the latter chipped with slight blows while the china plates did not chip.

TABLE 2.—DATA OF IMPACT TESTS ON SEVEN-INCH HEAVY SEMI-PORCELAIN HOTEL PLATES.

| Factory. | Plate. | Angle of swing in degrees. | Energy of impact, foot-pounds. | Thickness of bottom at thinnest point, in inches. | Energy of impact, per 0.001" thickness, foot-pounds. |
|---|---|---|---|---|---|
| A..... | 1 | 55 | 1.07 | 0.177 | |
| | 2 | 55 | 1.07 | 0.206 | |
| | 3 | 50 | 0.89 | 0.188 | |
| | 4 | 45 | 0.73 | 0.214 | |
| | 5 | 45 | 0.73 | 0.187 | |
| | 6 | 50 | 0.89 | 0.243 | |
| | Average..... | | 0.87 | 0.202 | 0.00430 |
| B..... | 7 | 75 | 1.86 | 0.251 | |
| | 8 | 65 | 1.44 | 0.246 | |
| | 9 | 60 | 1.25 | 0.242 | |
| | 10 | 70 | 1.64 | 0.252 | |
| | 11 | 60 | 1.25 | 0.243 | |
| | 12 | 50 | 0.89 | 0.243 | |
| | Average..... | | 1.37 | 0.246 | 0.00558 |
| C..... | 13 | 70 | 1.64 | 0.244 | |
| | 14 | 65 | 1.44 | 0.241 | |
| | 15 | 70 | 1.64 | 0.241 | |
| | 16 | 90 | 2.50 | 0.267 | |
| | 17 | 60 | 1.25 | 0.240 | |
| | 18 | 95 | 2.72 | 0.245 | |
| | Average..... | | 1.86 | 0.246 | 0.00752 |
| D..... | 19 | 60 | 1.25 | 0.276 | |
| | 20 | 55 | 1.07 | 0.295 | |
| | 21 | 35 | 0.45* | 0.284 | |
| | 22 | 50 | 0.89 | 0.276 | |
| | 23 | 55 | 1.07 | 0.286 | |
| | 24 | 50 | 0.89 | 0.293 | |
| | Average..... | | 1.03 | 0.285 | 0.00357 |

* Bad break, not included in average.

TABLE 3.—DATA OF IMPACT TESTS OF SEVEN-INCH HEAVY CHINA HOTEL PLATES.

| Factory | Plate. | Angle of swing, degrees. | Energy of impact, foot-pounds. | Thickness at bottom of thinnest point, inches. | Energy of impact per 0.001" thickness, foot-pounds. |
|---|---|---|---|---|---|
| E† | 25 | 45 | 0.73 | 0.240 | |
| | 26 | 60 | 1.25 | 0.210 | |
| | 27 | 40 | 0.58* | 0.218 | |
| | 28 | 50 | 0.89 | 0.222 | |
| | 29 | 50 | 0.89 | 0.214 | |
| | 30 | 55 | 1.07 | 0.229 | |
| | Average | | 0.97 | 0.222 | 0.00437 |
| F† | 31 | 45 | 0.73 | 0.228 | |
| | 32 | 70 | 1.64 | 0.227 | |
| | 33 | 45 | 0.73 | 0.228 | |
| | 35 | 65 | 1.44 | 0.229 | |
| | 34 | 55 | 1.07 | 0.229 | |
| | 36 | 55 | 1.07 | 0.242 | |
| | Average | | 1.11 | 0.230 | 0.00484 |
| G | 37 | 55 | 1.07 | 0.288 | |
| | 38 | 80 | 2.07 | 0.276 | |
| | 39 | 60 | 1.25 | 0.284 | |
| | 40 | 65 | 1.44 | 0.268 | |
| | 41 | 65 | 1.44 | 0.288 | |
| | 42 | 70 | 1.64 | 0.275 | |
| | Average | | 1.48 | 0.280 | 0.00528 |

* Bad break, not included in average.

† Roll edge plates; all the other plates used in the tests had heavy rims.

When the groups are rated according to energy of impact per 0.001 inch thickness of the bottom of the plates, taken as an index of the volume of the plates, the order in which they occur is materially changed. This point will be discussed after the porosity and density data for the plates have been presented.

## Porosity Determinations.

From the bottom of each plate broken in the impact tests, a piece weighing about 40 grams was taken for the porosity determinations, dried, and weighed. Saturation with distilled water was conducted by immersing the specimens in boiling water for 5 hours. After this, the weights of the saturated pieces

in air and suspended in water were determined. The absorption and porosity of each piece were calculated by the usual formulas.[1]

For calculating the bulk specific gravity the following formula was used:

Bulk specific gravity = D/W — S

in which

W = the saturated weight in air.
D = the dry weight.
S = the weight of the saturated piece suspended in water.

The term bulk specific gravity is used to avoid confusion, for while the expression "apparent specific gravity" is sometimes used to designate the specific gravity determined by the above formula, it is also applied to specific gravities calculated by a similar formula in which W — S in the above formula is replaced by D — S. The formula used for bulk specific gravity gives the weight of unit volume of a substance as it appears to the eye. The other formula gives the weight of unit volume of what has been called the skeleton of a substance, that is, the material not penetrable by water. We believe Potts and Knollman[2] were the first to use the expression bulk specific gravity.

When a substance is porous, bulk specific gravity can be determined by dividing the percentage porosity by the percentage absorption. That this relationship holds is shown by the equation

$$\frac{W - D/W - S}{W - D/D} = D/W - S.$$

For porous substances, then, the bulk specific gravity shows the ratio of percentage porosity to percentage absorption. Of course, this relationship does not hold true for averaged results.

The data for porosity and allied determinations are shown in Tables 4 and 5. In these tables we see that there was considerable variation in porosity and other values in each lot of semi-porcelain plates, and also in the average values of the various

[1] R. C. Purdy, *Bull.* **9**, Illinois Geol. Sur.

[2] *Trans. Am. Ceram. Soc.*, **15**, 353 (1913).

lots. In the hotel china plates the variations are, of course, not as great. It is interesting to note that there is seemingly no simple relationship between the data given here and the resistance to impact of the various lots of plates. This is due in large part to the fact that the plates varied in weight, bulk, and design.

TABLE 4.—ABSORPTION POROSITY AND BULK SPECIFIC GRAVITY OF SEVEN-INCH HEAVY SEMI-PORCELAIN HOTEL PLATES.

| Factory. | Plate. | Absorptions in percents of dry weights. | Open pores in percents of total volumes. | Bulk specific gravity. |
|---|---|---|---|---|
| A..... | 1 | 7.75 | 16.12 | 2.08 |
| | 2 | 6.44 | 13.71 | 2.13 |
| | 3 | 7.80 | 16.20 | 2.08 |
| | 4 | 8.18 | 17.00 | 2.08 |
| | 5 | 8.05 | 16.55 | 2.06 |
| | 6 | 9.42 | 19.02 | 2.02 |
| | Average..... | 7.94 | 16.43 | 2.075 |
| B..... | 7 | 8.09 | 16.80 | 2.08 |
| | 8 | 6.27 | 13.41 | 2.14 |
| | 9 | 7.87 | 16.25 | 2.06 |
| | 10 | 5.47 | 11.82 | 2.16 |
| | 11 | 5.03 | 10.98 | 2.19 |
| | 12 | 6.06 | 12.84 | 2.12 |
| | Average..... | 6.465 | 13.68 | 2.125 |
| C..... | 13 | 8.99 | 18.30 | 2.04 |
| | 14 | 9.24 | 18.71 | 2.03 |
| | 15 | 7.54 | 15.85 | 2.11 |
| | 16 | 9.39 | 19.15 | 2.04 |
| | 17 | 9.50 | 19.19 | 2.02 |
| | 18 | 8.56 | 17.40 | 2.04 |
| | Average..... | 8.87 | 18.10 | 2.047 |
| D..... | 19 | 12.05 | 23.52 | 1.95 |
| | 20 | 10.70 | 21.41 | 2.00 |
| | 21 | 11.73 | 23.02 | 1.96 |
| | 22 | 12.26 | 23.93 | 1.94 |
| | 23 | 11.82 | 23.19 | 1.96 |
| | 24 | 11.24 | 21.98 | 1.97 |
| | Average..... | 11.63 | 22.84 | 1.963 |

TABLE 5.—ABSORPTION, POROSITY AND BULK SPECIFIC GRAVITY OF SEVEN-INCH HEAVY CHINA HOTEL PLATES.

| Factory. | Sample. | Absorptions in percents of dry weights. | Open pores in percents of total volume. | Bulk specific gravity. |
|---|---|---|---|---|
| E† | 25 | 1.91 | 4.30 | 2.26 |
| | 26 | 0.43 | 1.05 | 2.38 |
| | 27 | 0.10 | 0.24 | 2.37 |
| | 28 | 0.23 | 0.55 | 2.34 |
| | 29 | 0.60 | 1.41 | 2.37 |
| | 30 | 0.47 | 1.11 | 2.36 |
| | Average | 0.62 | 1.44 | 2.35 |
| F† | 31 | 0.93 | 2.21 | 2.39 |
| | 32 | 0.79 | 1.91 | 2.40 |
| | 33 | 0.74 | 1.78 | 2.40 |
| | 34 | 0.94 | 2.24 | 2.38 |
| | 35 | 0.86 | 2.06 | 2.40 |
| | 36 | 0.90 | 2.12 | 2.36 |
| | Average | 0.86 | 2.05 | 2.39 |
| G | 37 | 0.0 | 0.0 | 2.35 |
| | 38 | 0.06* | 0.14* | 2.38 |
| | 39 | 0.0 | 0.0 | 2.38 |
| | 40 | 0.0 | 0.0 | 2.33 |
| | 41 | 0.03* | 0.07* | 2.35 |
| | 41 | 0.03* | 0.07* | 2.40 |
| | Average | 0.02* | 0.05* | 2.365 |

† Roll edge plates; all the other plates used in tests had heavy rims.
* Negligible.

TABLE 6.—RATING OF THE GROUPS OF PLATES[1] ACCORDING TO VARIOUS AVERAGE VALUES.

| Rank. | Energy of impact in ft. lbs. of blow producing fracture. | | Energy of impact in ft. lbs. per cubic inch of plate. | | Energy of impact in ft. lbs. per pound of material. | | Open pores in percents of total volume. | |
|---|---|---|---|---|---|---|---|---|
| | Factory. | Value. | Factory. | Value. | Factory. | Value. | Factory. | Value. |
| 1 | C | 1.86 | C | 0.925 | C | 1.255 | G | 0.05 |
| 2 | G | 1.48 | G | 0.794 | G | 0.934 | E | 1.44 |
| 3 | B | 1.37 | F | 0.721 | B | 0.926 | F | 2.05 |
| 4 | F | 1.11 | B | 0.710 | F | 0.840 | B | 13.68 |
| 5 | D | 1.03 | E | 0.638 | E | 0.755 | A | 16.43 |
| 6 | E | 0.97 | D | 0.493 | D | 0.696 | C | 18.10 |
| 7 | A | 0.87 | A | 0.442 | A | 0.588 | D | 22.84 |

[1] Plates from factories A, B, C, and D were heavy 7-inch semi-porcelain. Those from factories E and F were roll edge 7-inch vitrified hotel china. Those from factory G were 7-inch heavy vitrified hotel china.

From the data in Tables 2–5, it is a simple matter to calculate the energy of impact of the blow producing fracture per unit weight of material in the plates and for unit volume of the plates. These values are of importance for, other things being equal, the trade prefers the lightest and thinnest plates that will give the required service. The calculations have been made for the averages of the plates in each group and are shown in Table 6 together with the rating of the groups of plates according to other average values. The values per cubic inch of plate given in this table are a much more nearly accurate statement of the relation of the volume of the plates to resistance to impact than those derived from the thickness of the bottoms of the plates and shown in Table 2.

## SUMMARY.

1. It is possible to devise comparatively simple tests to determine the mechanical properties of such ceramic products as table wares.

2. The resistance to impact of the various makes of plates varied widely.

3. The vitrified hotel china plates tested were not superior as a class to the semi-porcelain plates in resistance to heavy impact blows. However, they did not chip with light blows while the semi-porcelain did.

4. There was no direct relation discernible between porosity and resistance to impact.

5. The design of plates undoubtedly is an important factor in determining their resistance to impact.

## AMERICAN CERAMIC SOCIETY.

### Acquisition of New Members during March, 1919.

*Resident Associate.*

**Acheson, A. E.,** J. H. Gautier & Co., Jersey City, N. J.
**Acki, S.,** Libbey-Owens Sheet Glass Co., Charleston, W. Va.
**Algeo, A. M.,** Hazel-Atlas Glass Co., Washington, Pa.
**Binns, Norah W.,** Alfred, N. Y.
**Bowman, Geo. H.,** 1931 E. 93rd St., Cleveland, Ohio.
**Bracken, Lloyd,** 770 Coleman Ave., Clarksburg, W. Va.
**Brooks, Charles T.,** 8205 Euclid Ave., Cleveland, Ohio.
**Cake, B. F.,** Denny-Renton Clay & Coal Co., Renton, Wash.
**Coe, John H.,** 547 Rosedale St., Wilkinsburg, Pa.
**Cruikshank, J. W.,** 1206 Hartje Bldg., Pittsburgh, Pa.
**Cunning, W. E.,** West End Pottery Co., East Liverpool, Ohio.
**Harvey, J. Ellis,** Orviston, Pa.
**Hewitt, L. C.,** Laclede-Christy Co., St. Louis, Mo.
**Hill, Jas. H.,** 706 Equitable Bldg., Los Angeles, Cal.
**Houser, A. T.,** Wood-Lloyd Co., Pittsburgh, Pa.
**Lemley, W. E.,** Denny-Renton Clay & Coal Co., Taylor, Wash.
**Lloyd, A.,** Hazel-Atlas Glass Co., Washington, Pa.
**Martin, Leonard A.,** Denny-Renton Clay & Coal Co., Seattle, Wash.
**Pickett, Thos. F.,** Hazel-Atlas Glass Co., Washington, Pa.
**Reddick, W. L.,** Hazel-Atlas Glass Co., Grafton, W. Va.
**Richardson, E. A.,** Glass Technology Dept., National Lamp Wks., Cleveland, Ohio.
**Saunders, Arthur E.,** Arkansas Glass Products Co., Van Buren, Ark.
**Strong, Thos. L.,** Strong Mfg. Co., Sebring, Ohio.
**Tait, Howard J.,** Phoenix Glass Co., Monaca, Pa.
**Troutman, Frank E.,** Standard Plate Glass Co., Butler, Pa.
**Wells, R. D.,** Floyd Wells Co., Royersford, Pa.

*Foreign Associate.*

**Carter, Charles,** Carter Encaustic Tile Wks., Poole, England.
**Eilers, H. F.,** Dominion Glass Co., Wallaceburg, Canada.
**Gibson, M. F.,** National Fireproofing Co., Toronto, Can.
**Searle, Alfred B.,** The White Building, Sheffield, England.
**Sieurin, Emil,** Hoganas, Sweden.

*Corporation.*

**Jones Hollow Ware Co.,** Baltimore, Md.
**Carborundum Company,** Niagara Falls, N. Y.

## AMERICAN CERAMIC SOCIETY.

### Associates Elevated to Active Membership at the Annual Meeting in Pittsburgh, February 5, 1919.

*Resident.*

Acheson, E. G.
Ashbaugh, Chas. C.
Bacon, Raymond F.
Bainbridge, W. L.
Barton, G. E.
Bell, M. L.
Bentley, L. L.
Berry, C. W.
Bole, G. A.
Booze, M. C.
Bowman, W. J. J.
Bryan, M. L.
Campbell, A. R.
Carder, F. R.
Cermak, Frank.
Child, J. L.
Clark, A. B.
Clark, Wm. M.
Conkling, S. O.
Cook, Chas. H.
Danielson, R. R.
Davis, John B.
Day, Arthur L.
Dornbach, Wm. E.
Duval, A. L.
Ellerbeck, Wm. L.
Fackt, Geo. P.
Frost, Leon, J.
Fulper, Wm. H.
Gillinder, James.
Gorton, A. F.
Greener, Geo. C.
Gregory, M. E.
Grueby, Wm. H.
Haaf, Geo.
Hall, Robert T.
Hansen, Abel.
Henry, Frank R.
Hipp, Wm. G.
Hoffman, Geo. E.
Hood, B. Mifflin.
Hornung, Martin R.
Jacobs, Wm. M.
Jeffery, Joseph A.
Jensen, Chas. H.
Jeppson, Geo. N.
Kalbfleisch, G. C.
Kanengeiser, Fred R.
Kerr, W. B.
Knight, M. A.
Kohler, W. J.
Landers, W. F.
Linbarger, S. C.
Maddock, A. M.
Maddock, John.
Malsch, Werner.
Maynard, T. Poole.
Mellor, F. G.
Metzner, Otto.
Middleton, Jefferson.
Mossman, P. B.
Muckenhirn, Chas. H.
McDougal, Taine G.
McDowell, J. S.
McElroy, R. H.
Ortman, Fred B.
Owens, Francis T.
Peregrine, C. R.
Poole, Joshua.
Rankin, G. A.
Rea, Wm. J.
Rhead, Frederick H.
Richardson, Ernest.
Riess, D. F.
Rusoff, Samuel.
Ryan, J. J.
Salisbury, B. E.
Sanders, John W.
Sant, Thomas H.
Scholes, Samuel R.
Seaver, Kenneth.
Sebring, Chas. L.
Shoemaker, Geo. W.
Singer, L. P.
Smith, James M.
Solon, Marc.
*Sosman, Robert B.
Staudt, August.
Steinhoff, F. L.
Sullivan, E. C.
Sweely, B. T.
Taylor, Royal W.
Taylor, Wm. C.
Tone, Frank J.
Townsend, Everett.
Treischel, Chester.
Truman, Gail R.
Walden, A. S.
Will, Otto W.
Wilson, Hewitt.
Zimmerli, Wm. F.

*Foreign.*

Carter, Owen.
Cobb, John W.
Cox, Paul E.
Luze, Henry de.
Emory, George.
Fredriksson, Nils.
Haviland, Jean.
†Lundgren, H. J.
Lusby, C. A.
Mellor, J. W.
Sailly, Paul.¶
Turner, W. E. S.
Walker, E. E.

* Elevated, March, 1919. † Died February, 1919.

## ACTIVITIES OF THE SOCIETY.

The following motions have recently been passed by the Board of Trustees:

*March 3rd.* It was voted to elevate Dr. Robert B. Sosman, of the Geophysical Laboratory, Washington, D. C., to Active Membership.

*March 10th.* It was voted to extend indefinitely the authorization of the Secretary to accept applications for Associate and Corporation memberships.

*March 20th.* It was voted to grant the Membership Committee the sum of $200 for its use in soliciting new members.

*March 20th.* It was voted to appropriate a sum not to exceed $2,000 for the conduct of new departments in the JOURNAL.

*March 25th.* It was voted to publish the minutes for 1918 at once instead of in the Year Book.

*March 28th.* It was voted to retain the membership of the Society in the National Fire Protection Association, with the suggestion that a committee be appointed by the President to represent the Society in this Association.

## AMENDMENTS TO THE RULES.

The following amendments to the Rules have been adopted by letter ballot:

SECTION II—"Membership"—Shall be amended to read:

(1) The Society shall consist of Honorary Members, Active Members, Associate Members, Affiliated Members, and Corporation Members.

(2) Corporation Members must be persons, firms, or corporations who, being interested in the Society, make such financial contributions for its support as are prescribed in Section III.

(3) The Board of Trustees shall in each regular meeting advance to Active Membership all Associate Members whose activity in the Society or whose prominence in the ceramic industries, in the opinion of a majority of the Board of Trustees, merits such recognition. Any Active Member may nominate in writing Associates for Active Membership and the Board of Trustees shall act on such recommendation at the next regular meeting of the Society. A written statement of the qualifications of each candidate shall be presented at that meeting of the Society and published promptly in the JOURNAL.

(4) Corporation members may be enrolled on the appropriate list of the Society at any time upon payment of the dues prescribed in Section III.

(5) All Honorary Members, Active Members, Associate Members, and Corporation Members shall be equally entitled to the privileges of member-

ship, except that only Active Members and one representative of each Corporation member shall be entitled to vote. Such representative shall be officially designated by the person, firm or corporation represented. Only active members shall be entitled to hold office. The roster of each grade of membership shall be printed separately in at least one publication issued by the Society annually.

(6) Any person may be expelled from any grade of membership of the Society if charges signed by five or more active members be filed against him or her, and if the Board of Trustees examine into and sustain said charges by a majority vote. Such person, however, shall first be notified of the charges against him and be given a reasonable time to appear before the Board of Trustees or to present a written defense, before final action is taken.

SECTION III—"Dues"—Shall be amended to read:

(7) On and after February 1, 1920, no initiation fee shall be levied or collected from Associates upon promotion to Active Membership. The annual dues for Active Members shall be fixed by the Board of Trustees, but shall not exceed ten dollars.

(8) Corporation Members shall pay no initiation fee. The annual dues shall be fixed by the Board of Trustees but shall not be less than twenty-five dollars. The privileges of membership shall begin upon payment of the annual dues.

SECTION IV—"Officers"—Shall be amended to read:

(9) The affairs of the Society shall be managed by a Board of Trustees consisting of the President, the Vice-President (an Honorary Secretary, if there be one), the Treasurer, the retiring president and his immediate predecessor, and three trustees. The President, the Vice-President and the Treasurer shall be elected to serve one year. The Trustees shall be elected to serve three years, one Trustee being elected each year.

(10) The President shall have general supervision of the affairs of the Society under the direction of the Board of Trustees and shall perform such other duties as pertain to his office.

(11) He shall countersign the checks drawn by the Treasurer when such drafts are known by him to be proper and duly authorized by the Board of Trustees.

(12) A Secretary shall be appointed annually by the Board of Trustees to serve for one year.

(13) He shall see that all moneys due the Society are carefully collected and deposited in a Bank approved by the Board of Trustees, and he shall transfer monthly such funds to the custody of the Treasurer. The Secretary shall carefully scrutinize all expenditures and use his best endeavors to secure economy in the administration of the Society. He shall personally investigate and certify the accuracy of all bills or vouchers on which money is to be paid. He shall have charge of the books of account of the Society and shall furnish monthly to the Board of Trustees a statement of monthly balances. He shall present annually to the Board of Trustees a balance sheet of his books as of

the 31st of December and shall furnish from time to time such other statements as may be required of him.

(14) The Secretary shall furnish a suitable bond for the satisfactory performance of his duties, which shall be held in the custody of the President.

(15) The Treasurer shall receive all moneys due the Society, and deposit the same in the name of the Society in a National Bank designated by the Treasurer and approved by the Board of Trustees. He shall invest all funds not needed for current disbursements, as shall be ordered by the Board of Trustees. He shall pay all bills by draft, when certified by the Secretary or as ordered by the Board of Trustees. He shall furnish a satisfactory bond for the proper performance of his duties, which shall be held in the custody of the President.

(16) All securities belonging to the Society shall be held in the custody of the Treasurer.

(17) The accounts of the Secretary and of the Treasurer shall be audited before each annual meeting by a certified public accountant or some other competent person designated by the Board of Trustees.

SECTION V—"Elections"—Shall be amended as follows:

(18) At the annual meeting a nominating committee of five active members, not officers, of the Society, shall be appointed.

(19) At least ninety days before the annual meeting this committee shall send the names of the nominees to the Secretary who will immediately send a copy of the same to each Active Member. Any five Active Members may act as a self-constituted Nominating Committee and present the names of any nominees to the Secretary, provided this is done at least thirty days before the annual meeting. The names of all nominees, provided their assent has been obtained before nomination, shall be placed on the ballot without distinction as to nomination by the regular or self-constituted Nominating Committee and shall be mailed to each Active Member, not in arrears, at least twenty days before the annual meeting. The voting shall be confined to the names appearing on this ballot. The ballot shall be enclosed in an envelope on which there shall be no mark for identification other than the word "Ballot." This envelope shall be enclosed in another envelope for mailing, addressed to the Secretary, upon the back of which the voter shall endorse his name. The ballot envelope shall be opened in the presence of three scrutineers appointed by the President, who will report the result of the election at the last session of the annual meeting. A plurality of affirmative votes cast shall elect.

SECTION VII—"Standing Committees"—Shall be amended as follows:

Standing Committees

(20) 5, "Local and Student Sections" to be
"Sections and Divisions"

(21) 8, "Military and Economic Preparedness" to be
"Research and Development"

(22) The Committee on Sections and Divisions shall consist of five mem-

bers. Its duties shall be to promote the organization of Local Sections, Student Branches, and Divisions.

(23) The Committee on Research and Development shall consist of five members. Its duties shall be to organize and encourage scientific investigations pertaining to the silicate and related industries, especially those investigations which will stimulate the development of our national industries and resources. It shall be empowered to coöperate with similar committees of other scientific societies and with Government bureaus.

SECTION VIII—"Divisions"—Shall be amended as follows:

(24) The affairs of a Division shall be managed by a Chairman, a Secretary-Treasurer, and a Council of four members. The officers of the Division and two members of the Council shall be elected annually by ballot at the last session of the Division held during the annual meeting of the Society and shall take office at the close of the meeting at which they are elected. All members of a Division are entitled to vote. The members of the Council shall hold office for two years. The officers shall hold office for one year or until their successors are elected. The Board of Trustees shall fill any vacancies occurring through death or resignation among officers of a Division.

(25) The Secretary-Treasurer of each Division shall make an annual report to the Society of the activities and finances of the Division.

SECTION XI—"Publications"—Shall be amended as follows:

(26) One copy of each issue of the paper-bound edition of the JOURNAL shall be sent prepaid to each member of the Society not in arrears. No member shall be furnished with more than one copy of each issue free for any single year. A member may be permitted to complete by purchase one file of the publications of the Society at less than the current commercial rate, the amount to be fixed by the Board of Trustees and to be called the member's rate.

## NOTICE TO MEMBERS.

The January, February and March numbers of the JOURNAL will be sent to members whose dues for the past year have been paid. If the dues for the current year are then unpaid the subscription will be discontinued.

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¶ Actual records were kept for 365 days of the burning of 9-inch, high-grade, refractory brick in one continuous tunnel kiln and in seven 30-foot round kilns, during which time 5,110,000 brick were burned in the tunnel kiln as against 5,040,000 in the seven round kilns.

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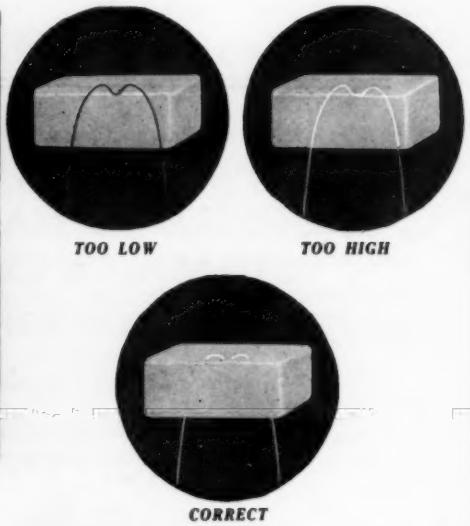


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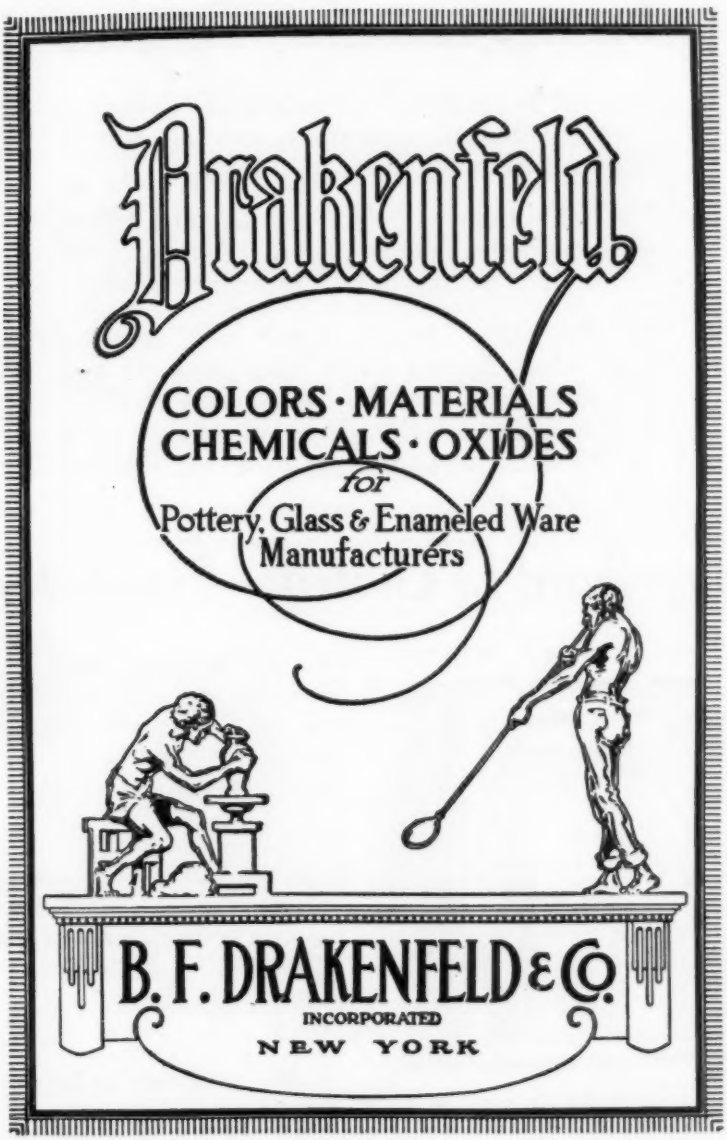
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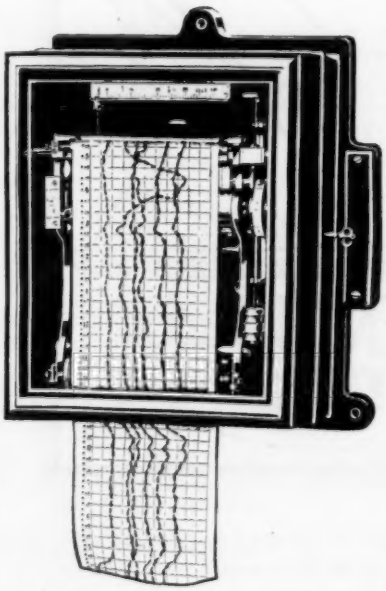

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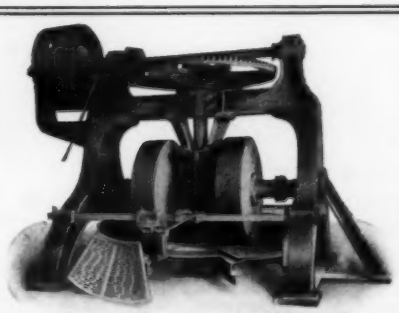

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